18141

ecological determinants of coastal area management

volume i — an overview

76
ity of north carolina
am publication
76-05

francis parker
david b
dirk f

Cover photograph
by
Jill Stivers

Donna Dyer 18141

ECOLOGICAL DETERMINANTS OF COASTAL AREA MANAGEMENT

VOLUME I -- AN OVERVIEW

Principal Investigators

David Brower

Dirk Frankenberg

Francis Parker

This work was sponsored by the Office of Sea Grant, NOAA, U.S. Dept. of Commerce, under Grant No. 04-6-158-44054, and the State of North Carolina, Dept. of Administration. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright that may appear hereon.

SEA GRANT PUBLICATION UNC-SG-76-05 APRIL, 1976

Sea Grant Program, 1235 Burlington Laboratories, N.C. State University, Raleigh, North Carolina 27607

Project Directors

David Brower, Principal Investigator
Center for Urban and Regional Studies

Dirk Frankenberg, Co-Principal Investigator
Director, Marine Sciences Program

Francis Parker, Co-Principal Investigator
Department of City and Regional Planning

THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
CHAPEL HILL, NORTH CAROLINA

Contributing Authors

Raymond Alden . . . . . Marine Sciences Program, UNC
Vincent Bellis. . . . . Department of Biology, ECU
Candace Carraway. . . . Joint Degree in Law and Planning Program, UNC
Edwin Chester . . . . . Joint Degree in Law and Planning Program, UNC
B. J. Copeland. . . . . Director, UNC Sea Grant Program
Glenn Dunn. . . . . Joint Degree in Law and Planning Program, UNC
Ron Fiore . . . . . Department of Zoology, NCSU
Val Klump . . . . . Marine Sciences Program, UNC
Wilson Laney. . . . . Department of Zoology, NCSU
Ed Pendelton. . . . . Department of Zoology, NCSU
Roger Pratt . . . . . Department of City and Regional Planning, UNC
Ed Proffitt . . . . . Department of Biology, ECU
Mary Joan Pugh. . . . . Department of City and Regional Planning, UNC
Johanna Smith . . . . . Marine Sciences Program, UNC
Nancy Tomkovick . . . . Marine Sciences Program, UNC
John Williams . . . . . Department of Zoology, NCSU

VOLUME I

ECOLOGICAL DETERMINANTS OF COASTAL ZONE MANAGEMENT

Contents

Page

PREFACE..... 1

INTRODUCTION AND SUMMARY..... 3

I. CONTEXT AND UNIFYING ENVIRONMENTAL PROCESSES OF THE NORTH CAROLINA COASTAL AREA..... 10

I.A. Barrier Island System..... 12

I.A.1. Energy Input..... 13
I.A.2. Sand Movement..... 18
I.A.3. Soil Porosity..... 20
I.A.4. Biotic Adaptations..... 21

I.B. Lagoon-Estuary System..... 22

I.B.1. Water Mixing Processes..... 23
I.B.2. Sediment Deposition and Environmental Diversity.. 26
I.B.3. Processes of Chemical Concentration..... 27
I.B.4. Biological Production..... 28

II. PROCESSES, POLICIES AND TOOLS..... 31

II.A. Barrier Island System..... 32
II.A.1. Ecological Processes in the Barrier Island System..... 32
II.A.2. Process Disturbing Activities in the Barrier Island System..... 33
II.A.3. Policy Implications for the Barrier Island System..... 36

II.A.3.a. The Beach..... 36
II.A.3.b. The Dunes..... 37
II.A.3.c. Washovers..... 38
II.A.3.d. Inlets..... 39
II.A.3.e. Aquifers..... 41
II.A.3.f. Maritime Forests..... 42

II.A.4. Management Tools and Techniques Applicable to Barrier Islands..... 44

Page

II.A.4.a. Local Tools and Techniques..... 44
II.A.4.b. State and Federal Tools and Techniques..... 64

II.B. Lagoon-Estuary System..... 66

II.B.1. Mid-Salinity System..... 71

II.B.1.a. Ecological Processes in the Mid-Salinity System..... 71
II.B.1.b. Destructive Human Activities in the Mid-Salinity System..... 73

(1) Upstream Perturbations in Watercourses..... 74

(a) Channelization..... 74
(b) Upstream damming, flood control and water diversion..... 75

(2) Local Perturbations in Estuary Shape..... 77
(3) Perturbations in Water Quality.. 79

(a) Industrial pollutants..... 80
(b) Agricultural and urban pollution..... 83
(c) Thermal pollution..... 85

II.B.1.c. Enforcement of Environmental Regulations by Municipalities..... 86

(1) Enforcement at the Local Level.. 86
(2) Enforcement at the State Level.. 86
(3) Enforcement at the Federal Level..... 89

II.B.2. Salt Marshes..... 91

II.B.2.a. Ecological Processes in the Salt Marsh..... 92
II.B.2.b. Process Disturbing Activities in the Salt Marsh..... 93
II.B.2.c. Policy Implications for the Salt Marsh..... 94

APPENDIX ONE (continued) Page

I.D. Maritime Forest..... 22
Vincent Bellis and Edward Proffitt

I.D.1. Definition and North Carolina Examples..... 23
I.D.2. Environmental Description..... 24

I.D.2.a. Stress Factors..... 24
I.D.2.b. Adaptations to Stress..... 24
I.D.2.c. Trophic Levels..... 25

I.D.3. Geographic Variations..... 26
I.D.4. Values of the Environment..... 26
I.D.5. Man's Impact on the Environment..... 27
I.D.6. Management Implications..... 27

I.E. Barrier Island Values and Man's Impact..... 28
Val Klump and Johanna Smith

I.E.1. Barrier Island Model..... 28
I.E.2. Values..... 29

I.E.2.a. Primary..... 29
I.E.2.b. Secondary (Indirect)..... 30
I.E.2.c. Aesthetic..... 31

I.E.3. Man's Potential Impact..... 31

I.E.3.a. Activities Intrinsically Dangerous..... 31
I.E.3.b. Beach Stabilization and Protection Measures..... 32
I.E.3.c. Construction and Development in the Dunes.. 37
I.E.3.d. Vehicular and Foot Traffic..... 37
I.E.3.e. Groundwater Extraction..... 37
I.E.3.f. Other Activities..... 37

I.E.4. Management Implications..... 38

I.F. Barrier Island Bibliography..... 40

II. LAGOON-ESTUARY SYSTEMS

II.A. Brackish Water Systems..... 46
B. J. Copeland

II.A.1. Environmental Description..... 46
II.A.2. Values of the Environment..... 48
II.A.3. Man's Impact on the Environment..... 48
II.A.4. Management Implications..... 51

APPENDIX ONE (continued) Page

II.B. Mid-Salinity Systems..... 51
Wilson Laney

II.B.1. Environmental Description..... 52
II.B.2. Biological Patterns..... 55
II.B.3. Values of the Environment..... 59
II.B.4. Man's Impact on the Environment..... 61
II.B.5. Management Implications..... 61

II.C. Mud and Mud Flats..... 64
John B. Williams

II.C.1. Environmental Description..... 64
II.C.2. Values of the Environment..... 71
II.C.3. Man's Potential Impact..... 72
II.C.4. Management Implications..... 73

II.D. Oyster Reefs..... 73
Ronald Fiore

II.D.1. Reef Description..... 73
II.D.2. Environmental Factors Affecting Oysters..... 74

II.D.2.a. Water Movement..... 74
II.D.2.b. Salinity..... 76
II.D.2.c. Temperature..... 77
II.D.2.d. Food..... 77

II.D.3. Character of the Bottom..... 79
II.D.4. Parasites, Commensals, Competitors and Predators... 80
II.D.5. Man's Potential Impact..... 81
II.D.6. Values of Oyster Reefs..... 85

II.E. Salt Marshes..... 88
Karen Bolster

II.E.1. Environmental Description..... 88

II.E.1.a. Horizontal Interactions..... 88
II.E.1.b. Vertical Interactions..... 94
II.E.1.c. Energy Pathways..... 97

II.E.2. Temporal Patterns..... 103
II.E.3. Organism Adaptations..... 105
II.E.4. Values of the Environment..... 105

II.E.4.a. Primary (Direct)..... 105
II.E.4.b. Secondary (Indirect)..... 107
II.E.4.c. Tertiary..... 107

Page

II.B.2.d. Management Tools and Techniques Applicable to Salt Marshes..... 95

(1) Local Tools and Techniques..... 96
(2) State and Federal Tools and Techniques..... 105

II.B.3. Mud and Sand Flats..... 109

II.B.3.a. Ecological Processes in the Mud and Sand Flats..... 110
II.B.3.b. Process Disturbing Activities in the Mud and Sand Flats..... 111
II.B.3.c. Policy Implications for the Mud and Sand Flats..... 111
II.B.3.d. Management Tools and Techniques Applicable to Mud and Sand Flats.. 112

II.B.4. Swamp Forests..... 117

II.B.4.a. Ecological Processes in Swamp Forests..... 118
II.B.4.b. Process Disturbing Activities in Swamp Forests..... 119
II.B.4.c. Policy Implications for Swamp Forests..... 121
II.B.4.d. Management Tools and Techniques Applicable to Swamp Forests..... 122

(1) Local Tools and Techniques..... 122
(2) State and Federal Tools and Techniques..... 130

GLOSSARY..... 134

VOLUME II: APPENDICES

APPENDIX ONE--COASTAL ECOLOGICAL SYSTEMS

Page

I. BARRIER ISLANDS

I.A. The Beach and Shoreface Dynamics..... 1
Val Klump and Johanna Smith

I.A.1. The Beach in Profile..... 2
I.A.2. Water-Sediment Transport..... 3

I.A.2.a. Normal Processes of Sediment Transportation..... 3
I.A.2.b. Sediment Transport Associated with Storms.. 6
I.A.2.c. Overall Sediment Budget..... 7

I.A.3. Barrier Island Migration..... 9
I.A.4. Capes and Cuspate Forelands..... 10
I.A.5. Washovers..... 10

I.B. Inlets..... 13
Val Klump and Johanna Smith

I.B.1. Physical Characteristics..... 13
I.B.2. Dynamic Characteristics..... 15

I.B.2.a. Tidal Currents..... 15
I.B.2.b. Longshore Currents and Transport..... 15
I.B.2.c. Deposition..... 15

I.B.3. Temporal Characteristics..... 18

I.B.3.a. Migration and Stability..... 18
I.B.3.b. Formation..... 18

I.C. Dunes..... 20
Val Klump and Johanna Smith

I.C.1. Physical Characteristics..... 20
I.C.2. Dynamic Characteristics..... 21

APPENDIX ONE (continued) Page

II.E.5. Man's Impact on the Environment..... 109
II.E.6. Management Implications..... 110

II.F. Swamp Forests..... 111
Nancy Tomkovick

II.F.1. Environmental Description..... 113

II.F.1.a. Swamp Forests..... 113
II.F.1.b. River Flood Plain Swamps..... 114
II.F.1.c. Pocosins..... 114

II.F.2. Pathways and Processes..... 115

II.F.2.a. Nutrient Cycle..... 115
II.F.2.b. Hydrological Cycle..... 116
II.F.2.c. Absorption and Sedimentation..... 116

II.F.3. Temporal Patterns (Succession)..... 116
II.F.4. Organism Adaptations..... 118
II.F.5. Values of the Environment..... 119

II.F.5.a. Primary..... 119
II.F.5.b. Secondary..... 120
II.F.5.c. Tertiary..... 121

II.F.6. Man's Potential Impact..... 123
II.F.7. Management Implications..... 125

II.G. Migrating Organisms..... 125
Edward Pendleton

II.G.1. Migrations of Offshore Spawners (Nursery Utilizers). 126

II.G.1.a. Shrimp..... 126
II.G.1.b. Blue Crabs..... 128
II.G.1.c. Fish (Menhaden, Flounder, Spot and Croaker)..... 129

II.G.2. Anadromous Fish..... 131
II.G.3. Catadromous Fish..... 133
II.G.4. Birds..... 134
II.G.5. Man's Potential Impact..... 137

II.H. Lagoon-Estuary Bibliography..... 142

APPENDIX TWO--TOOLS AND TECHNIQUES FOR
COASTAL AREA MANAGEMENT

Page

Preface..... 163

I. LAND ACQUISITION

I.A. Land Acquisition..... 165

I.B. Land Banking..... 167

I.B.1. Advance Site Acquisition..... 167

I.B.1.a. Authority..... 167
I.B.1.b. Viability..... 167
I.B.1.c. Where It Has Been Used and to What Effect.. 167
I.B.1.d. Legal Issues..... 168
I.B.1.e. Coastal Applications..... 168

I.B.2. Growth Management..... 170

I.B.2.a. Authority..... 170
I.B.2.b. Viability..... 170
I.B.2.c. Where It Has Been Used and to What Effect.. 172
I.B.2.d. Legal Issues..... 172
I.B.2.e. Coastal Application..... 173

I.C. Transferable Development Rights (TDR)..... 175

I.C.1. Authority..... 176
I.C.2. Viability..... 176
I.C.3. Appropriate Level of Government..... 176
I.C.4. Where It Has Been Used and to What Effect..... 176
I.C.5. Legal Issues..... 178
I.C.6. Coastal Application..... 178

I.D. Acquisition of Less Than Fee Interests..... 180

I.D.1. Authority..... 180
I.D.2. Viability..... 181
I.D.3. Where It Has Been Used and to What Effect..... 182
I.D.4. Legal Issues..... 182
I.D.5. Coastal Application..... 183

APPENDIX TWO (continued) Page

I.E. Fee Simple Acquisition..... 184

I.E.1. Authority..... 184
I.E.2. Assisting Authority..... 184
I.E.3. Viability..... 184
I.E.4. Where It Has Been Used and to What Effect..... 185
I.E.5. Legal Issues..... 185
I.E.6. Coastal Application..... 186

I.F. Compensable Regulation..... 188

I.F.1. Authority..... 188
I.F.2. Viability..... 189
I.F.3. Where It Has Been Used and to What Effect..... 191
I.F.4. Legal Issues..... 191
I.F.5. Coastal Application..... 192

I.G. North Carolina Land Conservancy Corporation..... 193

I.G.1. Authority..... 193
I.G.2. Viability..... 193
I.G.3. Coastal Application..... 193

I.H. Land and Water Conservation Fund..... 194

I.H.1. Authority..... 194
I.H.2. Assisting Authority..... 194
I.H.3. Viability..... 194
I.H.4. Coastal Application..... 194

I.I. The Nature Conservancy..... 196

I.I.1. Authority..... 196
I.I.2. Coastal Application..... 196

II. PUBLIC SPENDING

II.A. Introduction..... 199

II.B. Capital Programing..... 201

II.B.1. Authority..... 201
II.B.2. Viability..... 201
II.B.3. Where It Has Been Used and to What Effect..... 202
II.B.4. Legal Issues..... 202
II.B.5. Coastal Application..... 202

APPENDIX TWO (continued) Page

II.C. Urban and Rural Service Areas..... 203

II.C.1. Authority..... 203
II.C.2. Where It Has Been Used and to What Effect..... 203
II.C.3. Legal Issues..... 204
II.C.4. Coastal Application..... 204

II.D. Acquisition..... 205

II.D.1. Authority..... 205
II.D.2. Viability..... 205
II.D.3. Where It Has Been Used and to What Effect..... 206
II.D.4. Legal Issues..... 206
II.D.5. Coastal Application..... 206

II.E. Utilities Extension..... 207

II.E.1. Authority..... 207
II.E.2. Viability..... 207
II.E.3. Where It Has Been Used and to What Effect..... 208
II.E.4. Legal Issues..... 208
II.E.5. Coastal Application..... 209

II.F. Development Timing..... 211

II.F.1. Authority..... 212
II.F.2. Viability..... 212
II.F.3. Where It Has Been Used and to What Effect..... 213
II.F.4. Legal Issues..... 213

II.F.4.a. Substantive Due Process..... 213
II.F.4.b. The Taking Issue..... 215
II.F.4.c. Right to Travel..... 215
II.F.4.d. Equal Protection..... 216

II.F.5. Coastal Application..... 216

II.G. Access to Existing Facilities..... 218

II.G.1. Authority..... 218
II.G.2. Viability..... 218
II.G.3. Where It Has Been Used and to What Effect..... 218
II.G.4. Legal Issues..... 219
II.G.5. Coastal Application..... 219

APPENDIX TWO (continued) Page

III. TAXATION

III.A. Introduction..... 221

III.A.1. Public Purpose..... 221
III.A.2. Arbitrary, Capricious..... 221
III.A.3. Substantial Equity..... 222
III.A.4. Uniformity..... 222

III.B. Income Tax-Excess Profit Tax..... 224

III.B.1. Authority..... 224
III.B.2. Viability..... 225
III.B.3. Where It Has Been Used and to What Effect..... 225
III.B.4. Legal Issues..... 225
III.B.5. Coastal Application..... 225

III.C. Cost-Benefit Taxation (User Service Charges, Land Service Charges)..... 226

III.C.1. Authority..... 226
III.C.2. Viability..... 226
III.C.3. Where It Has Been Used and to What Effect..... 227
III.C.4. Legal Issues..... 227
III.C.5. Coastal Application..... 227

III.D. Special Assessments..... 228

III.D.1. Authority..... 228
III.D.2. Viability..... 228
III.D.3. Where It Has Been Used and to What Effect..... 228
III.D.4. Legal Issues..... 228
III.D.5. Coastal Application..... 229

III.E. Preferential Assessment of Property (Use-Value Assessment Taxation)..... 230

III.E.1. Authority..... 232
III.E.2. Assisting Authority..... 232
III.E.3. Viability..... 233
III.E.4. Legal Issues..... 233
III.E.5. Coastal Application..... 234

III.F. Land Gains Taxation..... 236

III.F.1. Authority..... 237
III.F.2. Viability..... 237
III.F.3. Where It Has Been Used and to What Effect..... 237
III.F.4. Legal Issues..... 237
III.F.5. Coastal Application..... 238

APPENDIX TWO (continued) Page

IV. DEVELOPMENT REGULATION

IV.A. Introduction..... 239

IV.A.1. Constitutional Challenges..... 239
IV.A.2. Challenges Based on Inadequate Authority..... 241
IV.A.3. Procedural Due Process Challenges..... 241

IV.B. Interim or Temporary Development Regulations..... 244

IV.B.1. Authority..... 244
IV.B.2. Viability..... 244
IV.B.3. Where It Has Been Used and to What Effect..... 245
IV.B.4. Legal Issues..... 245
IV.B.5. Coastal Application..... 246

IV.C. Zoning..... 248

IV.C.1. Conventional Zoning..... 248

IV.C.1.a. Authority..... 248
IV.C.1.b. Viability..... 248
IV.C.1.c. Where It Has Been Used and to What Effect..... 249
IV.C.1.d. Legal Issues..... 249
IV.C.1.e. Coastal Application..... 250

IV.C.2. Exclusive Agricultural or Nonresidential Zones..... 252

IV.C.2.a. Authority..... 252
IV.C.2.b. Viability..... 252
IV.C.2.c. Where It Has Been Used and to What Effect..... 252
IV.C.2.d. Legal Issues..... 253
IV.C.2.e. Coastal Application..... 253

IV.C.3. Minimum Lot Size..... 254

IV.C.3.a. Authority..... 255
IV.C.3.b. Viability..... 255
IV.C.3.c. Where It Has Been Used and to What Effect..... 255
IV.C.3.d. Legal Issues..... 256
IV.C.3.e. Coastal Application..... 256

APPENDIX TWO (continued) Page

IV.C.4. Height Restrictions..... 258

IV.C.4.a. Authority..... 258
IV.C.4.b. Viability..... 258
IV.C.4.c. Where It Has Been Used and to What Effect..... 258
IV.C.4.d. Legal Issues..... 258
IV.C.4.e. Coastal Application..... 258

IV.C.5. Mandatory Low Income Housing Construction Ordinance..... 259

IV.C.5.a. Authority..... 259
IV.C.5.b. Viability..... 260
IV.C.5.c. Where It Has Been Used and to What Effect..... 260
IV.C.5.d. Legal Issues..... 261
IV.C.5.e. Coastal Application..... 262

IV.C.6. Conditional and Contractual Zoning..... 263

IV.C.6.a. Authority..... 263
IV.C.6.b. Viability..... 263
IV.C.6.c. Where It Has Been Used and to What Effect..... 264
IV.C.6.d. Legal Issues..... 264
IV.C.6.e. Coastal Application..... 264

IV.C.7. Special Exception..... 266

IV.C.7.a. Authority..... 266
IV.C.7.b. Viability..... 266
IV.C.7.c. Where It Has Been Used and to What Effect..... 267
IV.C.7.d. Legal Issues..... 267
IV.C.7.e. Coastal Application..... 268

IV.C.8. Variance..... 269

IV.C.8.a. Authority..... 269
IV.C.8.b. Viability..... 269
IV.C.8.c. Where It Has Been Used and to What Effect..... 269
IV.C.8.d. Legal Issues..... 269
IV.C.8.e. Coastal Application..... 270

APPENDIX TWO (continued) Page

IV.C.9. Minimum Floor Space Requirement..... 271

IV.C.9.a. Authority..... 271
IV.C.9.b. Viability..... 271
IV.C.9.c. Where It Has Been Used and to What Effect..... 271
IV.C.9.d. Legal Issues..... 271
IV.C.9.e. Coastal Application..... 272

IV.C.10. Regulation of Multi-Family Housing..... 273

IV.C.10.a. Authority..... 273
IV.C.10.b. Viability..... 273
IV.C.10.c. Legal Issues..... 273
IV.C.10.d. Coastal Application..... 274

IV.C.11. Bonus and Incentive Zoning..... 275

IV.C.11.a. Authority..... 275
IV.C.11.b. Viability..... 275
IV.C.11.c. Where It Has Been Used and to What Effect..... 275
IV.C.11.d. Legal Issues..... 276
IV.C.11.e. Coastal Application..... 276

IV.C.12. Floating Zones..... 278

IV.C.12.a. Authority..... 278
IV.C.12.b. Viability..... 278
IV.C.12.c. Where It Has Been Used and to What Effect..... 278
IV.C.12.d. Legal Issues..... 279
IV.C.12.e. Coastal Application..... 279

IV.C.13. Performance Zoning and Performance Control for Sensitive Lands..... 280

IV.C.13.a. Authority..... 280
IV.C.13.b. Viability..... 280
IV.C.13.c. Where It Has Been Used and to What Effect..... 281
IV.C.13.d. Legal Issues..... 281
IV.C.13.e. Coastal Application..... 282

IV.D. Regulation of Development..... 284

APPENDIX TWO (continued) Page

IV.D.1. Planned Unit Development (PUD) and Cluster or Average Density Zoning..... 284

IV.D.1.a. Authority..... 284
IV.D.1.b. Viability..... 285
IV.D.1.c. Where It Has Been Used and to What Effect..... 285
IV.D.1.d. Legal Issues..... 285
IV.D.1.e. Coastal Application..... 286

IV.D.2. Traditional Subdivision Regulation..... 288

IV.D.2.a. Authority..... 288
IV.D.2.b. Viability..... 289
IV.D.2.c. Where It Has Been Used and to What Effect..... 289
IV.D.2.d. Legal Issues..... 289
IV.D.2.e. Coastal Application..... 291

IV.D.3. Subdivision Controls Relating to Off-Site Facilities..... 293

IV.D.3.a. Authority..... 293
IV.D.3.b. Viability..... 294
IV.D.3.c. Where It Has Been Used and to What Effect..... 294
IV.D.3.d. Legal Issues..... 294
IV.D.3.e. Coastal Application..... 295

IV.E. Numerical Restraints or Quota Systems..... 296

IV.E.1. Total Population or Quota Systems..... 296

IV.E.1.a. Authority..... 296
IV.E.1.b. Viability..... 296
IV.E.1.c. Where It Has Been Used and to What Effect..... 296
IV.E.1.d. Legal Issues..... 296
IV.E.1.e. Coastal Application..... 297

IV.E.2. Population and Employment Targets..... 298

IV.E.2.a. Authority..... 298
IV.E.2.b. Viability..... 298
IV.E.2.c. Where It Has Been Used and to What Effect..... 298
IV.E.2.d. Legal Issues..... 298
IV.E.2.e. Coastal Application..... 298

APPENDIX TWO (continued) Page

IV.E.3. Annual Permit Limits..... 300

IV.E.3.a. Authority..... 300
IV.E.3.b. Viability..... 300
IV.E.3.c. Where It Has Been Used and to What Effect..... 300
IV.E.3.d. Legal Issues..... 301
IV.E.3.e. Coastal Application..... 301

IV.F. Official Mapping..... 302

IV.F.1. Authority..... 302
IV.F.2. Viability..... 302
IV.F.3. Where It Has Been Used and to What Effect..... 302
IV.F.4. Legal Issues..... 302
IV.F.5. Coastal Application..... 303

IV.G. Regional Anti-Exclusion Techniques..... 304

IV.G.1. Authority..... 304
IV.G.2. Viability..... 305
IV.G.3. Where It Has Been Used and to What Effect..... 305
IV.G.4. Coastal Application..... 305

IV.H. Building Inspection..... 306

IV.H.1. Authority..... 306
IV.H.2. Assisting Authority..... 306
IV.H.3. Viability..... 306
IV.H.4. Where It Has Been Used and to What Effect..... 307
IV.H.5. Legal Issues..... 307
IV.H.6. Coastal Application..... 308

IV.I. Regulation of Mobile Homes..... 309

IV.I.1. Authority..... 309
IV.I.2. Viability..... 309
IV.I.3. Where It Has Been Used and to What Effect..... 309
IV.I.4. Legal Issues..... 309
IV.I.5. Coastal Application..... 310

IV.J. Municipal Enforcement of Restrictive Covenants..... 312

IV.J.1. Authority..... 312
IV.J.2. Viability..... 313
IV.J.3. Where It Has Been Used and to What Effect..... 313
IV.J.4. Legal Issues..... 313

APPENDIX TWO (continued) Page

IV.J.4.a. Due Process..... 313
IV.J.4.b. Public Purpose..... 314

IV.J.5. Coastal Application..... 314

V. ENVIRONMENTAL REGULATION

V.A. Locally Administered Regulation..... 317

V.A.1. Local Health Regulation..... 317

V.A.1.a. Authority..... 317
V.A.1.b. Administration and Enforcement..... 317
V.A.1.c. Coastal Application..... 318

V.A.2. Sand Dune Protection Ordinance..... 319

V.A.2.a. Authority..... 319
V.A.2.b. Viability..... 319
V.A.2.c. Where It Has Been Used and to What Effect.. 320
V.A.2.d. Legal Issues..... 320
V.A.2.e. Coastal Application..... 320

V.A.3. Local Environmental Impact Ordinances..... 322

V.A.3.a. Authority..... 322
V.A.3.b. Viability..... 322
V.A.3.c. Where It Has Been Used and to What Effect.. 323
V.A.3.d. Legal Issues..... 323

V.B. State Administered Regulations..... 325

V.B.1. Regulation of Public Drinking Water Supplies..... 325

V.B.1.a. Authority..... 325
V.B.1.b. Assisting Authority..... 325
V.B.1.c. Administration and Enforcement..... 325
V.B.1.d. Coastal Application..... 326

V.B.2. Mosquito Control..... 327

V.B.2.a. Authority..... 327
V.B.2.b. Administration and Enforcement..... 327
V.B.2.c. Coastal Application..... 327

APPENDIX TWO (continued) Page

V.B.3. Prohibited Discharge to Water..... 328

V.B.3.a. Authority..... 328
V.B.3.b. Administration and Enforcement..... 328
V.B.3.c. Coastal Application..... 328

V.B.4. Regulation of Solid Waste Disposal Sites..... 329

V.B.4.a. Authority..... 329
V.B.4.b. Administration and Enforcement..... 329
V.B.4.c. Viability..... 329
V.B.4.d. Coastal Application..... 329

V.B.5. Prohibited Discharges (Ocean Disposal)..... 330

V.B.5.a. Authority..... 330
V.B.5.b. Administration and Enforcement..... 330
V.B.5.c. Coastal Application..... 330

V.B.6. Regulation of Construction of Water Wells..... 331

V.B.6.a. Authority..... 331
V.B.6.b. Administration and Enforcement..... 331
V.B.6.c. Coastal Application..... 331

V.B.7. Regulation of Septic Tanks..... 332

V.B.7.a. Authority..... 332
V.B.7.b. Administration and Enforcement..... 332
V.B.7.c. Viability..... 332
V.B.7.d. Coastal Application..... 333

V.B.8. Obstruction of Navigable and Open Waters..... 334

V.B.8.a. Authority..... 334
V.B.8.b. Administration and Enforcement..... 334
V.B.8.c. Coastal Application..... 334

V.B.9. Air Pollution Control Permits..... 335

V.B.9.a. Authority..... 335
V.B.9.b. Administration and Enforcement..... 335
V.B.9.c. Viability..... 336
V.B.9.d. Coastal Application..... 336

APPENDIX TWO (continued) Page

V.B.10. Licensing and Regulation of Pesticide Application... 337

V.B.10.a. Authority..... 337
V.B.10.b. Administration and Enforcement..... 337
V.B.10.c. Viability..... 337
V.B.10.d. Coastal Application..... 338

V.B.11. Environmental Pesticide Control..... 339

V.B.11.a. Authority..... 339
V.B.11.b. Administration and Enforcement..... 339
V.B.11.c. Viability..... 339
V.B.11.d. Coastal Application..... 339

V.B.12. Regulation of Oil Refineries..... 341

V.B.12.a. Authority..... 341
V.B.12.b. Administration and Enforcement..... 341
V.B.12.c. Coastal Application..... 341

V.B.13. Control of Coast Wetlands Activities..... 342

V.B.13.a. Authority..... 342
V.B.13.b. Administration and Enforcement..... 342
V.B.13.c. Coastal Application..... 342

V.B.14. Dredge and Fill Permits..... 343

V.B.14.a. Authority..... 343
V.B.14.b. Administration and Enforcement..... 343
V.B.14.c. Coastal Application..... 343

V.B.15. Regulation of Water Capacity Use Areas..... 345

V.B.15.a. Authority..... 345
V.B.15.b. Administration and Enforcement..... 345
V.B.15.c. Coastal Application..... 346

V.B.16. Dam Approval..... 347

V.B.16.a. Authority..... 347
V.B.16.b. Administration and Enforcement..... 347
V.B.16.c. Coastal Application..... 347

V.B.17. Regulations Pursuant to Erosion and Sedimentation Control Plans..... 348

V.B.17.a. Authority..... 348

APPENDIX TWO (continued) Page

V.B.17.b. Administration and Enforcement..... 348
V.B.17.c. Viability..... 348
V.B.17.d. Where It Has Been Used and to What Effect..... 349
V.B.17.e. Coastal Application..... 349

V.B.18. Oil Petroleum Control Program..... 350

V.B.18.a. Authority..... 350
V.B.18.b. Administration and Enforcement..... 350
V.B.18.c. Coastal Application..... 350

V.B.19. Regulation of Mining Operations..... 351

V.B.19.a. Authority..... 351
V.B.19.b. Coastal Application..... 351

V.B.20. Regulation of Oil and Gas Wells..... 352

V.B.20.a. Authority..... 352
V.B.20.b. Administration and Enforcement..... 352
V.B.20.c. Coastal Application..... 352

V.B.21. North Carolina Environmental Policy Act of 1971..... 353

V.B.21.a. Authority..... 353
V.B.21.b. Viability..... 353
V.B.21.c. Where It Has Been Used and to What Effect..... 353
V.B.21.d. Legal Issues..... 354
V.B.21.e. Coastal Application..... 354

V.B.22. A-95 Review..... 356

V.B.22.a. Authority..... 356
V.B.22.b. Administration and Enforcement..... 356
V.B.22.c. Coastal Application..... 357

V.C. Environmental Regulation (Federal)..... 358

V.C.1. National Environmental Policy Act of 1969 (NEPA)..... 358

V.C.1.a. Authority..... 358
V.C.1.b. Validity..... 358
V.C.1.c. Where It Has Been Used and to What Effect.. 359
V.C.1.d. Legal Issues..... 359
V.C.1.e. Coastal Application..... 359

APPENDIX TWO (continued) Page

V.C.2. National Flood Insurance Program..... 362

V.C.2.a. Authority..... 362
V.C.2.b. Viability..... 362
V.C.2.c. Where It Has Been Used and to What Effect.. 363
V.C.2.d. Legal Issues..... 364
V.C.2.e. Coastal Application..... 364

V.C.3. National Pollution Discharge and Elimination System (NPDES)..... 366

V.C.3.a. Administration and Enforcement..... 366
V.C.3.b. Viability..... 366
V.C.3.c. Coastal Application..... 366

V.C.4. Ocean Dumping Permit..... 367

V.C.4.a. Authority..... 367
V.C.4.b. Viability..... 367
V.C.4.c. Coastal Application..... 367

V.C.5. Regulation of Bridges Over Navigable Waters..... 368

V.C.5.a. Authority..... 368
V.C.5.b. Coastal Application..... 368

V.C.6. Permits for Dredge and Fill and for Structures Other Than Bridges In or Over Navigable Waters..... 369

V.C.6.a. Authority..... 369
V.C.6.b. Administration and Enforcement..... 369
V.C.6.c. Coastal Application..... 370

VI. REGULATION OF DEVELOPMENT IN AREAS OF ENVIRONMENTAL CONCERN

IV.A. Introduction..... 371
IV.B. Authority..... 372
IV.C. Viability..... 373
IV.D. Where It Has Been Used and to What Effect..... 374
IV.E. Legal Issues..... 375
IV.F. Coastal Application..... 377

SELECTED BIBLIOGRAPHY..... 379

PREFACE

This report is a synthesis of natural science information relating to the North Carolina coastal area, followed by policy and management implications of that information. The material was prepared jointly by the Marine Sciences Program and the Center for Urban and Regional Studies; both are parts of the University of North Carolina. The report draws on two lengthy appendices: "Ecological Determinants," prepared by the Marine Sciences Program, and "Tools and Techniques for Coastal Area Management" prepared by the Center for Urban and Regional Studies. These appendices are bound separately as Volume II of this report, but the table of contents is included in this volume for reference.

The report is intended to be useful to those state officials charged with responsibility for coastal area management in North Carolina under the Coastal Area Management Act of 1974, including the Coastal Resources Commission and Coastal Resources Advisory Council. It is also intended for those county and municipal planners and officials charged with responsibility for preparing local plans and programs under the Coastal Area Management Act. It is hoped that the information in this report will also be of interest to other officials and citizens in the coastal area, but there has been no effort to summarize the report for a larger audience. A shorter version of the report will be prepared later for widespread distribution.

Overall direction and guidance for this project has been provided by the principal investigators, but many of the individual sections have been written by graduate students in Marine Sciences, in City and Regional Planning, and in the Joint Degree in Law and Planning at the University of North Carolina. Authorship of individual marine science sections is indicated in the report, while authorship of the tools and techniques sections was in every sense a collective effort of the Planning and Law students. While they were responsible for the section as a whole, it would be unrealistic to identify individual authors of sections in Appendix Two.

This project was conducted under a grant from the University of North Carolina Sea Grant Program, B. J. Copeland, Director.

INTRODUCTION AND SUMMARY

The North Carolina coastal area is a unified ecological system, in which individual environments are linked together by unifying processes, including energy related processes of sand and water movement, mixing processes involving transfer between salt and freshwater environments, and migration processes of organisms which make up the food chain. These processes integrate the functions of the individual environments--the salt marshes, the estuary, the barrier islands, the ocean--into a single functioning whole. The coastal area is a unified system, and changes in one component of the system may have harmful effects which appear throughout the system.

For purposes of analysis, two major environmental systems are identified: the barrier island system and the lagoon-estuary system. While each is dependent on the other, they may be described in terms of the processes which are most essential to each.

For the barrier island, dominant processes are the energy related processes of wind and wave action. The islands are shaped by the interaction of those processes, and in their natural condition have a substantial ability to absorb changes in energy levels and processes. By absorbing energy, including peak storm surges as well as daily tidal and current actions, the barrier island protects the more fragile and productive environments of the lagoon and estuary. In responding to energy changes the barrier islands are in a state of dynamic stability, and must necessarily change their profile and shape in response to seasonal variations and peak storm conditions.

The lagoon estuary system is characterized by mixing and transport processes. Tidal ebbs and flows, fresh and salt water fluctuations, and other periodic shifts within the system create a variety of different environments for the organisms which comprise the food chain, and also provide the transport processes necessary to move organisms to different environments during their life cycle, and to bring all parts of the system into functioning relationships with other parts. It is this continual interchange within the system, and with the open ocean, which makes the lagoon-estuary system so productive. Individual environments, such as tidal marshes, may be valuable in themselves, but their real contribution occurs when they can interact with the larger system of which they are a part.

The value of the coastal environments is dependent on their ability to function together as part of an overall system. This is the basic policy implication of North Carolina's Coastal Area Management Act, this report, and is the basis for recommending specific tools by which development in the coastal area may be guided or controlled. Policies and tools are suggested for individual environments on the basis of their usefulness in maintaining the inherent natural system values of these environments.

While this report focuses on the natural systems and their implications for coastal management, it is important to remember that this is not the only argument for effective coastal management. This report has not dealt with the issues of esthetics and appearance in the coastal area, but this is not because the authors feel it to be unimportant. On the contrary,

the visual quality of the coast is so important that it requires specific consideration by itself. The purpose of this report is to focus on one aspect of coastal management: maintaining the viability of the natural systems and environments. To this should be added the appropriate consideration for esthetics, for natural hazards and for the costs of servicing development.

This report is organized around two basic systems, the barrier island and the lagoon-estuary, and divided further into individual environments within each system. It will be apparent that there is some overlap with the potential areas of environmental concern (AEC's) which are defined in the North Carolina Coastal Area Management Act of 1974 and in the guidelines issued under this act by the Coastal Resources Commission. There is not, however, a one-to-one correspondence between the environments discussed in this report and the potential AEC categories. Environments are analyzed here as parts of an overall ecological system, whereas AEC categories have been identified on the basis of several different criteria, including a natural hazard criteria and a uniqueness or scarcity value criteria as well as natural system viability.

This report does not take issue with the proposed AEC's, but believes that they do not by themselves constitute a complete management solution. The AEC's are initially designated as interim areas only, carrying no enforcement powers. Until the interim areas are converted to final designated areas, the AEC process will be an informational process only, and management will depend entirely on some of the tools

suggested in this report. Even after the final AEC's are designated, and a permit process instituted for development within the AEC's, there will be a need to augment the AEC process with other tools which together make up a development guidance system. This is particularly true since the AEC permits will apply only within designated AEC's, whereas the developments with potential harmful impact may occur upstream from the designated area, in an area linked to the AEC by groundwater or surface runoff flows, or in other ways which affect the specific AEC through disturbances elsewhere in the system. Within each section of the report, AEC designation is discussed as one relevant tool, but it is assumed that this alone will be insufficient unless coordinated with other tools operating in areas outside the AEC.

Discussion of individual tools is provided in Volume II, Appendix Two (see Table of Contents). Tools are grouped there according to four major categories: (1) tools involving acquisition of land or interests in land; (2) tools involving the provision, scheduling, or withholding of public services; (3) tools involving the application of taxation to influence or guide development; and (4) tools involving regulation. This last category is further divided between regulations which focus on development control (such as zoning) and regulations with a primary environmental focus, whether at local, state or Federal level. The AEC process, because of its obvious importance in the North Carolina Coastal Zone, is treated separately.

As catalogued in Appendix Two, each tool is described in terms of its purposes, its present applications, its apparent success or failure, and its present legal status. It should be noted that some of the tools described are not presently authorized under North Carolina law. Others have questionable authority or, while having legal authority, have not yet been implemented in North Carolina or specifically in the coastal counties. While clearly stating these problems, it was felt important to include these tools for several reasons. Lack of legal authority may preclude immediate use of a tool, but may suggest the need for new legislation if the tool can be shown to be appropriate to North Carolina. Lack of application in the coastal counties may reflect the generally low level of staffing available for planning and enforcement. This is a current and real problem, particularly for some of the more flexible and sophisticated tools, but if coastal area management is to be seriously pursued, there will have to be a commitment to increased inspection and enforcement staffs throughout the area. Tools which are inapplicable under present manpower circumstances will become relevant as staffs are expanded.

In the present volume, those tools are suggested which are believed to be most applicable to the natural system problems of individual environments. A clear distinction is made between those tools which are currently applicable and those which, while potentially useful in that environment, will depend on changes in enabling authority. Applicable

tools are listed in the general order in which they appear in the appendix. They are not listed in order of priority, but their relative importance is identified within the text.

The suggested mix of tools varies according to the environment. In general, regulation and land acquisition are believed to be most effective, followed by service extension and spending. Taxation, while an important auxiliary factor, is unlikely to play a major role in influencing development.

Regulation, including traditional local zoning as well as environmental controls, remains a key technique in areas such as the barrier island system where most pressure for development is occurring. It is important to realize the extent to which one tool may depend on, and extend the usefulness of, other categories of tools. A natural complement may exist between environmental regulation and public spending or service provision on the barrier island. If environmental regulations covering septic tank standards are strongly enforced, the result will be to effectively preclude most large-scale barrier island development dependent on individual treatment systems. In this case, the provision and timing of public sewer facilities will become the dominant guiding tool. Land acquisition is seen as generally a lower priority tool on the barrier islands, not due to any lack of effectiveness but due to the extremely high cost of acquiring land under such inflated prices as currently exist. Land acquisition may play a role in specific critical areas when sources of support can be secured.

In the much more dynamic situation of the lagoon-estuary system it is harder to determine tools with a direct application to protecting the natural processes involved. In general, the mix of local tools may be inevitably smaller, with more reliance on state level environmental regulation. Land and water acquisition may play a larger role in protecting the lagoon-estuary systems than it does on the barrier island, particularly since title to some such areas already rests, in principle, with the state. Before expending large sums to acquire and protect such areas, it would seem important to further pursue the question of existing state titles, and not build up a precedent of paying or compensating for rights which may be legally determined to rest with the state.

I

CONTEXT AND UNIFYING ENVIRONMENTAL PROCESSES OF THE NORTH CAROLINA COASTAL AREA

1

CONTEXT AND UNIFYING ENVIRONMENTAL PROCESSES OF THE NORTH CAROLINA COASTAL AREA

The North Carolina coastal zone consists of a gradual transition from land to sea. As one moves across it towards the ocean the land flattens and rivers, estuaries, and bays increasingly dominate the landscape. The gradual nature of the coastal transition makes any system of environmental classification artificial. In this report we discuss coastal zone environments in separate chapters and as parts of two environmental systems, but the reader should be aware that this procedure is more a matter of convenience than of environmental reality. Each environment and system is intimately linked to others by proximity, water exchanges, organism migrations and common environmental processes. Thus the environmentalist, like the tourist, is impressed by the unity of the coastal zone rather than by the separateness of its parts. A tourist sees the coastal zone as site for beach combing, fishing, seafood, and sun. The environmentalist sees it as an area in which shifting landforms provide highly structured and productive environments that maintain large numbers of marine and estuarine organisms. In both cases the observer sees the coastal zone as a unitary system rather than a sum of its separate parts. We hope the reader will bring the same bias to his comprehension of this report.

Two major types of environmental systems occur in the North Carolina coastal zone: the barrier island system at the ocean edge; and the lagoon-estuary system further inland. The barrier island system is dominated by processes that dissipate ocean-derived energy and includes such areas of environmental concern as offshore sandbars, beaches, dunes, washover fans, maritime forests and tidal inlets. The lagoon-estuary is dominated by processes of freshwater/seawater mixing and includes such areas as sounds, estuaries, tidal flats, salt marshes, oyster reefs and swamp forests.

This section seeks to describe the dominant processes and geographic context that shape and unite environments within these two major systems. Similar processes occur in all environments, but each environment represents a unique balance so generally similar areas differ from one another in their environmental specifics.

A. Barrier Island System

The barrier island system is characterized by high physical energy, sand movement, and by high soil porosity. Barrier island environments are exposed to ocean derived energy from winds, waves, currents and tides. Most of this energy is dissipated by the movement of sand within the system. During periods of relatively constant energy input, an equilibrium of sand movement occurs and geological structures are maintained despite the high energy impinging upon them. The increased energy input found during storm conditions causes structures within the system to

move and change shape as energy is absorbed. Redistribution of sand following extreme conditions often regenerates the original structures because the characteristic instability of the sediments allows the system to "bend but not break" as storm energies are dissipated. The looseness of the sediments associated with constant sand movement makes barrier island soils highly porous and permeable. The high porosity is an important characteristic that influences and shapes processes within the system.

1. Energy Input

Most of the energy that moves sand within the barrier island system is ultimately derived from winds over the ocean. Wind energy moves sand grains directly in exposed areas, while wind driven waves and currents move them along the sea bottom. The surface winds that convey energy to barrier islands on the North Carolina coast are controlled by two basic weather patterns. In summer, the coastal area is dominated by a high pressure center over Bermuda resulting in southwesterly winds over the coast. During the winter, the Bermuda High moves east and North Carolina's coast becomes dominated by a high pressure system located over the mid-eastern U.S. that produces northeasterly winds. Variable winds occur as influence is shifted between the two high pressure systems. Table 1 shows maximum and average wind speeds and direction for the Cape Hatteras area.

TABLE 1

Surface Winds at Cape Hatteras

Month	J	F	M	A	M	J	J	A	S	O	N	D
Average Wind Direction	NE	NE	SW	SW	SW	SW	SW	SW	NE	NE	NE	NE
Average Wind Velocity	12.9	13.4	12.6	12.5	11.6	11.2	10.6	10.0	11.0	11.9	11.7	12.0
Maximum Wind Velocity	42	58	60	61	40	43	58	48	72	60	54	45
Direction of Maximum Wind	NE	SW	NW	SW	SW	NE	S	SW	S	NW	SW	NE

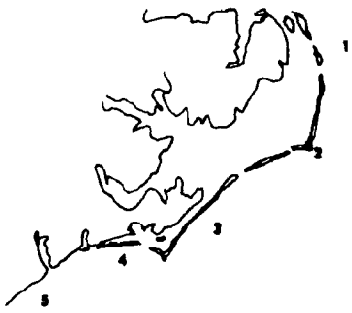
Extreme winds from storms may accelerate or change patterns of sand and surface water transport to cause drastic physical changes in shoreline and alter normal patterns in shelf circulation. The coastline changes shape and new inlets may even form in response to wind energy in a single storm. Table 2 shows the probability of coastal areas being hit by storms of different magnitudes. North Carolina's geographic location with respect to major frontal systems makes the probability of storm occurrences quite high for the coastal zone area. In the years from 1901 to 1963, North Carolina's coast was hit by 163 tropical storms and 70 hurricanes. In addition, violent local disturbances, tornadoes and water spouts, occur frequently with 34 reported in the 13 year period 1960 to 1973.

Winds create waves by perturbing the flatness of the sea into wavelets that absorb additional wind energy to grow into waves. Wave growth is related to the speed and duration of the winds that create them. Once formed, waves transport energy efficiently along their travel paths, ultimately losing it rapidly as they break on shore. On a steep shore, the waves break near the waterline and large amounts of wave energy are concentrated to erode the beach. As this erosion occurs, however, sand is deposited offshore, the angle of the coast decreases, and breaking wave energy is dissipated over a wider area thereby decreasing beach erosion. Thus beach erosion and sand bar formation are integral parts of natural beach erosion control processes. The slope of the shore, the position of the breaker zone, and the processes of erosion and deposition

TABLE 2

Probability of Storms

Sector	% Probability Tropical Storm	% Probability Hurricane	% Probability Great Hurricane
1	9	8	4
2	18	11	8
3	14	5	-
4	7	6	2
5	13	6	2



eventually reach a state of dynamic equilibrium, reflecting the wave energy regime that changes with changing wind patterns. In North Carolina, summer waves come from the southwest and have a mean height of two feet, while winter waves come from the northeast and have a mean height of four feet. Aperiodic storms may shift wave direction and increase wave energies by an order of magnitude. The barrier island system therefore is stable only until a change of energy pattern upsets the existing dynamic equilibrium.

Winds also create currents by pushing masses of water up against a coast. Since winds and waves seldom strike the coast "head-on," longshore currents are usually set up along the beach. These currents are directed by the angle at which winds and waves strike the beach. In North Carolina, the variability of shape and orientation of barrier island components, as well as the seasonality of wind-wave patterns, makes variable longshore currents a characteristic feature of nearshore oceanography.

Tides also effect the coastal zone environment. Tides sweep across ocean basins to cause periodic oscillations in sea height and current pattern along coastlines. North Carolina has two high tides and two low tides each day causing four alternating periods of ebb and flow currents and a range of sea level height of three to four feet. The major impact of tidal current energy is felt in the inlets between barrier islands, but wind driven currents also show tidal effects in their pattern of variation through time.

2. Sand Movement

North Carolina's barrier islands are composed of sand. Sand moves as ocean derived energy is absorbed by the barrier island. Medium grained sand particles are most susceptible to the processes of both erosion and deposition (Riedl and McMahan, 1974). Surprisingly, finer particles (muds and clays) resist erosion because, when deposited, they form a smooth surface over which water currents flow without disturbance. Paradoxically, fine grained sediments also resist deposition because once in suspension they sink so slowly that they tend to be carried along by currents rather than sink to the bottom. Therefore, once the fine particles are in suspension they are likely to be transported out of the system, leaving medium grain sand to absorb much of the ocean-devised energy. Since sand sized sediment is easily suspended and rapidly deposited, sand erosion, transport, and deposition processes are efficient mechanisms of energy absorption. An equilibrium is reached within the system as sand grains move from offshore bars, to channels, to beaches, to dunes and back again in response to wind, wave, current and tidal effects. The continuous balance between sand movement and the barrier island stability is the most important characteristic of the barrier island system.

The equilibrium and maintenance of geological structures within the barrier island system are greatly affected by differential energy input. As a result, the barrier islands change shape in response to energy changes. Energy changes are difficult to predict however since the

total energy impinging on the barrier island is a result of complex interactions between wind, waves, currents and tidal stage. Thus barrier island morphology is notoriously unstable; shoals shift, channels fill in, beaches erode, dunes develop blowouts, washover fans are aperiodically active and inlets migrate. Predictions of these events can only be statistical, e.g. once every 25 years a storm of sufficient energy to open new inlets will occur on the North Carolina coast. Man's development of barrier islands must therefore recognize the general instability of the environment and the basic unpredictability of its most dramatic, and damaging changes. A reasonable response to this characteristic of the environment would be to leave the most unstable areas (inlets, beaches, and dunes) undeveloped and to accept the risk of loss elsewhere. Attempts to stabilize high energy barrier island environments ultimately fail, sometimes dramatically as storms undermine and destroy the structures, and sometimes gradually as with the slow disappearance of the environment the structures sought to stabilize. Structures that seek to alter rather than stop sand movement can succeed in one area, but almost always create problems elsewhere by concentrating destructive erosional forces outside the "stabilized" area. Thus artificial preservation of part of the barrier island usually occurs at the expense of other areas in the same system. The barrier island must be able to move and change shape to absorb energy. Any interference with these processes undermines the function of the system as a "barrier" and the processes of regeneration that maintain it.

3. Soil Porosity

The porous nature of the sandy barrier island soils has important implications for the system. It has been suggested that high energy sandy beaches are important in filtering, processing and remineralizing organic matter and pollutants (Riedl and McMahan, 1974). This process involves conversion of the dissolved materials into particulate foam, which is filtered through the porous soils of the beach and processed by the microscopic biota that live between the sand grains. These organisms feed on the organics and release carbon dioxide and nutrients that flow back to the seawater to be utilized in the process of primary production. The "beach-filter mechanism" depends on highly porous sandy soils to allow the flow-through filtration of the water and to provide interstitial living space for the biotic "processors."

The high porosity of sandy sediments allows both fresh and salt water to perculate through the spaces between the sand grains. The general looseness and permeability of coastal zone sediments allows fresh groundwater to extend to a depth of several hundred feet. For the same reasons, however, the sediments allow seawater striking the subsurface sea/land interface to move landward into the water table and replace fresh water under the barrier island system. In such areas, freshwater wells may become salty. Thus overpumping of freshwater wells may cause salt water incursion from below.

The highly porous soils of the barrier island system also creates sewage disposal problems. Sewage from septic tanks moves quickly through the permeable soil and reaches the water table before natural decomposition

can occur. This situation can become a health hazard when an over-developed area depends on the same water table for both drinking water and sewage disposal.

4. Biotic Adaptations

The biota of the barrier island system have adaptations that allow them to live in a high energy environment with an unstable substratum. Plants on the barrier islands are, for the most part, adapted to living in arid, shifting sands. These plants form extensive root systems near the sand surface to collect rain water before it filters through the porous soil. Dune plant root systems stabilize the dune surface against erosion by high wind energy. This natural dune stabilization process maintains itself at no cost to man since the plants grow through new layers of sand as they are deposited, but the shallow root systems are extremely sensitive to physical disturbance. Therefore man's activities can easily destroy this natural system of dune stabilization.

The animals of the barrier island system have adapted to the unstable high energy environment by three alternate life styles: living on the surface while avoiding high energy areas; burrowing beneath the surface; and living between the sand grains. The animals that live on the surface (shore-birds, fishes, insects) feed on burrowing forms or on dead materials that have been transported onto the beach. These organisms tend to be the most obvious animals on the barrier island because they must be large and fast enough to avoid or resist the high energy conditions. The burrowing forms are not so obvious (snails,

bivalves, crustacea, etc.). These animals may feed on materials in the water or dead materials on the exposed beach, but they move and burrow quickly to avoid high wave energy. The small animals that live between the sand grains are possibly the most important animals in the barrier island system (ciliates, tardigrades, turbellarions, copepods, etc.). These animals have developed many fascinating adaptations to their difficult environment, but their importance lies in their extremely large numbers and their role in the "beach-filter-mechanism" of processing and recycling of organic matter and pollutants.

B. Lagoon-Estuary System

The lagoon-estuary system is characterized by mixing processes, sediment deposition, environmental diversity and high productivity. Sea water is transported through inlets by tide and wind to mix with freshwater supplied by land runoff. Particulate materials settle from the fresh and sea waters in the quiet areas behind the barrier islands to form areas of fine grained bottom sediments. Barrier island systems protect the lagoon-estuary system from high ocean energies and allow highly diverse geologic structures to develop within the lagoon-estuarine region. Within a little over 300 linear miles of North Carolina coast, the lagoon-estuary system forms thousands of miles of coastline and millions of acres of estuarine habitats used as breeding and nursery areas by many important species. Food webs that supply these species are supported by the high productivity of the marshes and estuaries.

The productivity of the lagoon-estuary is attributable to high concentrations of nutrients that accumulate within the system and the mixing processes that make these materials available to plants.

1. Water Mixing Processes

The dominant feature of the lagoon-estuary system is the integration of aquatic influence from the sea and land. Sandy sediments, saline waters and migrating organisms are introduced to the lagoon-estuary from the ocean. Fine grained sediments, nutrients, organic matter, and fresh water are introduced to the system by land runoff in rivers. The materials from land and ocean are mixed by wind driven waves and currents, tidal action, and river flow to produce the rich and productive environments of the lagoon-estuary system.

The sea water entering the lagoon-estuary provides a stabilizing force to the system. The ocean provides a consistently high supply of inorganic chemicals reflected in the nearly constant salinity of sea water (ca. 3.5%). Water temperature in the lagoon-estuary is also stabilized by oceanic influence, as seasonal fluctuations in air temperature are rendered less extreme by their proximity to the thermally more stable sea waters. Periodic tidal flushing circulates and removes water and its contained wastes in the lagoon-estuary system. Migrating marine organisms periodically enter the lagoon-estuary system to increase the system's biota and, in many cases, provide commercially important harvests for man. North Carolina is unusual in that Cape Hatteras represents an environmental dividing line between warm water animals of the Carolinian

faunal assemblage and the colder water forms of the Virginian province (Cerame-Vivas and Gray, 1966; Vernberg and Vernberg, 1970). Thus, the lagoon-estuary system is regularly invaded by "common" migrating species and aperiodically entered by species at the southern or northern limits of their range (Wells and Gray, 1960).

The land derived fresh water runoff flows into the lagoon-estuary system from a system of rivers. The average flow of North Carolina's rivers tends to be lower than those of northern states, but the sediment and organic input of runoff is nonetheless quite high (Newton et al., 1974). It has been estimated that the fresh water input of all rivers entering the Pamlico-Albemarle Sound complex is, on an annual basis, roughly equal to the total volume of the Sounds (University of Rhode Island, 1973). The long residence time of runoff in the Sounds and estuaries couples with the relatively heavy riverine sediment load to make the estuarine areas a concentration point for materials carried by the rivers. Thus upland pollution may become more concentrated in the lagoon-estuary system than in the rivers that drain the uplands.

Wind driven waves and currents stir the lagoon estuary waters, but the protected nature of these waters prevents mixing from being complete and gradients of land and sea influence exist. As one moves landward from the ocean the influence of the sea declines, so salinities and sandy sediments decrease and temperature fluctuations increase. Conversely, as one moves seaward from the rivers, land influence declines, nutrient and sediment loads of the water decrease while water temperature

fluctuations also decrease. Environments within the lagoon-estuary system reflect various combinations of land and sea influence, and local energy regimes.

The horizontal environmental gradients found in the lagoon-estuary are reflected in the biota inhabiting various areas. Not surprisingly, the dominant organism inhabiting the environments within the system changes as the salinities decrease landward. Thus, for intertidal salt marshes a gradual change occurs from rush and salt marsh cordgrass dominated marshes near the ocean, to cattail dominated marshes in the low salinity systems. A similar gradient occurs in animals with scallops and hard clams in high salinities, oysters in mid-salinity areas and Rangia clams in the low salinity areas. Virtually all organisms in the lagoon-estuary system are adapted to tolerate a wide range of environmental conditions, but most cannot live throughout the entire gradient and thus each species inhabits only optimum ranges within it.

Vertical gradients also occur when mixing energies are so low that the water column "stratifies" and fresh water runoff flows out over heavier salt water to form a two-layered water column. Stratification of this sort impedes the chemical exchanges that normally take place between bottom sediments and the water column. Oxygen fails to get to the bottom and the resulting low oxygen conditions may kill bottom dwelling forms. Decomposition of these organisms compounds the low oxygen problem by further draining the oxygen supply. Stratification also impedes cycling of nutrients and organic matter between the sea bottom

and the water column so that nutrients build up to abnormal levels in the bottom layers. These nutrients can be mixed suddenly into the water column when normal mixing is reestablished producing blooms of noxious algae and eutrophication. In North Carolina, stratification may take place in the headwaters of tidal creeks during periods of high runoff. For the most part, however, the lagoon-estuary system itself is well mixed vertically, expediting exchange processes from the surface to the bottom.

2. Sediment Deposition and Environmental Diversity

The topography of the lagoon estuary system reflects a balance between sediment supply and the depositional/erosional power of water currents. Deeper water channels are maintained by tidal currents and river flow, but most of North Carolina's lagoon-estuary system is shallow (2 - 6 meters), reflecting the generally slow currents within the system. Sedimentary particles settle from these slow flowing currents to form sand and mud deposits. Geologists refer to the lagoon-estuary system as generally depositional indicating that fine grained materials tend to accumulate within them. Local currents set up erosion-deposition patterns that create diverse micro-environments within the accumulating materials. Juvenile organisms utilize these micro-environments as shelter from predators, and, as a result, the lagoon-estuary system is an important nursery area for many commercially important species.

3. Processes of Chemical Concentration

The lagoon-estuary is also a concentration point for materials needed for biological production. Nutrients and organic matter are brought to the lagoon-estuary by river runoff and ocean winnowing, and concentrated within the system by the processes of freshwater/seawater mixing and sediment deposition. As a result, the sediments of the lagoon-estuary are rich in organic matter and nutrients. These materials cycle from sediments to water to biota and support high photosynthetic production of plant material.

Just as sediments, nutrients and organisms are concentrated in the lagoon-estuary, so too are pollutants. Toxic substances such as pesticides and industrial wastes, as well as pathogens from human wastes, that enter the lagoon-estuary system from rivers can accumulate in sediments and become concentrated in the organisms. Shellfish such as oysters concentrate disease causing bacteria, and viruses, as well as toxic heavy metals. Once part of a food chain, pollutants may be concentrated by feeding processes as the pollutant-contaminated organic matter is passed from one species to the species that feeds upon it. Thus larger commercially important animals are likely to become highly polluted, even though the pollutant may be fairly dilute in the environment. Once pollutants have been accumulated in the lagoon-estuary system, they are difficult to remove, because they are usually concentrated in the sediments. Thus these pollutants may pose a continuing hazard to the biota and, through contamination of food species, to man as well.

4. Biological Production

High concentrations of nutrients and organic materials coupled with mixing and flushing processes make the lagoon-estuary the system with nearly the highest level of biological production of any natural system. The abundance of plants is obvious in marshes, where vast quantities of stalked grasses dominate the landscape, but high production also occurs in open waters where blooms of all but invisible algae are important. Both grass and algal materials may act as a direct food source for some commercially important species; and, equally importantly, serve as the basic energy source for food webs that support all animals in the system. Many commercial species enter the estuaries to feed and reproduce at times when primary production is high, thereby maximizing biotic utilization of energy (Odum et al., 1974). Thus, alteration of land runoff, inhibition of recycling processes, destruction of marshlands, or elimination of food chain species can all reduce the ability of the system to produce commercially important species.

References

Bumpus, D. F., 1973. A description of the circulation on the continental shelf of the east coast of the United States. In Progress in Oceanography. B. A. Warren (ed.), pp. 111-157.

Cerame-Vivas, M. J. and I. E. Gray, 1966. The distribution pattern of benthic invertebrates of the continental shelf of North Carolina. Ecology 47(2): pp. 260-270.

Edzwald, J K., 1972. Coagulation of estuaries. Sea Grant Publication, UNC-SG-72-06, 204 pp.

Jackson, T. (ed.), 1969. Estuarine resources. Published by the North Carolina Wildlife Resources Commission.

LeGrand, H. E., 1961. Summary of geology of the Atlantic coastal plain. Bull. Am. Assoc. Petrol Geol. 45(9): pp. 1557-1571.

Maker, J. C., 1965. Correlations of subsurface Mesozic and Cenozoic rocks along the Atlantic coast. Am. Assoc. Petrol. Geol. Pub. Tulsa, Okla., pp. 18.

Murdorff, M. J., 1945. Progress report on grand water in North Carolina. N. C. Dept. Consv. and Dev. Bull. 47.

Newton, J. G., O. H. Pilkey and J. O. Blanton, 1971. An oceanographic atlas of the Carolina continental margin. Duke University Marine Laboratory. Published by the Division of Mineral Resources of the North Carolina Department of Conservation and Development. 57 pp.

Odum, H. T., B. J. Copeland and E. A. McMahan, 1974. Coastal ecological systems of the United States. Vol. II. Published by the Conservation Foundation, Washington, D. C., pp. 315-330.

Richards, H. G., 1967. Stratigraphy of Atlantic coastal plain between Long Island and Georgia: Review. Bull. Am. Assoc. Petrol. Geol. 51(12): pp. 2400-2429.

Riedl, R. and E. A. McMahan, 1974. High energy beaches. In Coastal ecological systems of the United States. Vol. I. H. T. Odum, B. J. Copeland and E. A. McMahon (eds.), The Conservation Foundation, Washington, D. C., pp. 180-251.

Richards, H. G., 1950. Geology of the Coastal plain of North Carolina. Trans. Am. Phil. Soc. New Services 40(1): pp. 83.

Roelofs, E. W. and D. F. Bumping, 1953. The hydrography of the Pamlico Sound. Bull. Mar. Sci. Gulf. Carrib. 3(3): pp. 181-205.

Ruzecki, E. P., 1974. A socio-economic environmental baseline summary for the south Atlantic region between Cape Hatteras, North Carolina and Cape Canaveral, Florida. Vol. II, Climatology. Prepared by the Virginia Institute of Marine Science for the Bureau of Land Management under Contract No. EQ4AC007 with the Council on Environmental Quality.

Schumacher, J. D., 1974. A study of near bottom currents in Carolina shelf waters. Ph.D. thesis, 1974. Marine Sciences Curriculum, University of North Carolina.

Spangler, W. B., 1950. Subsurface geology of Atlantic coastal plain of North Carolina. Bull. Am. Assoc. Petrol. Geol. 34(1): pp. 100-132.

Steffansson, U., L. P. Atkinson and D. F. Bumpus, 1971. Hydrographic properties and circulation of the North Carolina shelf and slope waters. Deep-Sea Res. vol. 18(4): pp. 383-420.

Taylor, H. F., 1951. Survey of marine fisheries of North Carolina. UNC Press, pp. 253.

University of Rhode Island, 1973. Coastal and offshore environmental inventory. Marine Publication Series #2. University of Rhode Island, Kingston, R. I.

Wells, H. W. and I. E. Gray, 1960. The seasonal occurrence of Mytilus edulis on the Carolina coast as a result of transport around Cape Hatteras. Biol. Bull. Mar. Biol., Woods Hole, 119, pp. 550-559.

Vernberg, F. J. and W. B. Vernberg, 1970. Lethal limits and the zoogeography of the faunal assemblages of coastal Carolina waters. Mar. Biol. 6: pp. 26-32.

II

PROCESSES, POLICIES, AND TOOLS

II

PROCESSES, POLICIES, AND TOOLS

A. The Barrier Island System

1. Ecological Processes

The ecological ingredients of the barrier island system have been addressed earlier in this report, and are discussed at length in Appendix One of Volume II. For our purposes, however, the general causal processes that shape the characteristics of the barrier islands can be summarized as follows:

--The energy regime, including wave climate, storm frequency, and current patterns

--Dynamic equilibrium of deposition, erosion and transport processes acting on the sediment supply

--Long term sea level fluctuations

--Water percolation due to porosity of sandy sediments

The interaction of these general causal processes shapes the barrier islands, and may be observed in the following visually identifiable results or processes:

--Daily, seasonal, and storm alteration of barrier island profile

--Landward migration and retreat of the barrier island

--Sand dune formation and migration, and the development of washovers and blowouts in the dunes

--Inlet formation and migration

--Maintenance of groundwater level and quality

When allowed to function naturally these processes ensure the continued maintenance of the barrier island system. The State of North Carolina has a deep interest in preserving the barrier island system because it bears the brunt of oceanic forces that would otherwise jeopardize the mainland; it provides navigation channels for man and migratory pathways for marine life between coastal sounds and the open ocean; it supplies materials and sediments essential to the development and growth of North Carolina's highly productive marshlands; and it contains many unique ecosystems and esthetic resources.

Unfortunately, because of its richness, the barrier island is subject to numerous competing pressures for use of its resources. The inevitable conflict of uses threatens to degrade seriously the barrier island environment, both in its role as an ecosystem and as a site for potential human development and activity. In its natural condition the barrier island system is highly resilient and able to absorb much punishment, but this environment can be easily damaged by human activity.

2. Process Disturbing Activities in the Barrier Islands

Briefly stated, when man alters the barrier island processes he lessens the island's ability to react to daily as well as storm action, which in turn results in devastation of human structures, and of the barrier island. The activities that disrupt the processes of the barrier island system can be grouped into four categories:

--construction and development

Examples: Construction of roads that necessitate protection from oceanic forces, encourage development in hazardous areas,

and serve as floodways for storm surge. Structures located in environmentally hazardous areas necessitating beach protection and physically altering the natural topography of the barrier island. Major public investment projects or intensive land uses placed in hazardous areas of barrier islands encouraging related development as well as necessitating beach protection and stabilization.

--alteration of primary dunes

Examples: Leveling and/or relocation of primary dune reducing island's resiliency to oceanic forces. Structures located on dunes or within the natural migration path of the dune, eliminating its responsiveness to storm events. Vehicular or foot traffic on dunes, killing vegetation essential for maintenance of dune system. Introduction of exotic plant species to stabilize dune movement artificially, thwarting the natural migration of the dune.

--groundwater extraction and contamination

Examples: Excessive groundwater extraction for public water supply resulting from over development, which lowers the water table in the dune system or maritime forest and may kill stabilizing vegetation. Septic tank contamination of the groundwater table resulting from overly dense development. Retardation of recharge resulting from construction of impervious surfaces, particularly paving. Destruction of vegetation that facilitates recharge.

--beach protection and stabilization, maintenance of navigation channels

Examples: Erection of groins, seawalls, bulkheads, and other engineering devices designed to impede natural oceanic currents and sand transport, usually constructed in order to protect strips of urbanized development located in hazardous island areas. From shoreline erosion dredging, construction of jetties, sand bypass systems and other methods used to maintain navigation channels through inlets, thus thwarting natural deposition of sand, migratory patterns of marine species, self-maintenance of barrier island, and contributions to marsh substrate.

One way to protect the barrier island environment and the ecological processes in that environment would be to prohibit development along the entire North Carolina coastline. While this approach would protect the coast, it would overlook other values that the coast provides to the North Carolina citizenry, particularly in terms of recreation. Thus while a no development policy might be appropriate for certain parts of the barrier island, generally a more realistic policy is one that allows development to occur on the barrier island, provided it is consistent with the natural processes.

In the barrier island the coastal processes can be said to express themselves in six component environments: (1) beach; (2) dunes; (3) washovers; (4) inlets; (5) aquifers; and (6) maritime forests. Below are described the distinctive features and management implications for

each of these environments. It must be remembered that these distinctions are made solely for convenience and that the crucial coastal processes have ramifications for the entire barrier island system. Accordingly, those areas of the barrier island that do not fall into the above groupings should still be managed with the view that unless the basic barrier island processes are protected, wherever they may occur, the barrier island system itself is jeopardized.

3. Policy Implications for the Barrier Islands

a. The Beach

The beach is the place where the land meets the ocean. It is shaped by the repetitive onshore movement of waves by longshore currents generated when waves hit the beach at an angle, and by sea level rise. These three different directions of water movement in turn mean that the various grades and sizes of sand that compose the beach are constantly in movement. The shape of the beach, and consequently the shape of the barrier island, is directly related to the direction and intensity of water movement and the supply of sand. Any attempt to make this inherently dynamic system "stable" by altering water flow or sand supply is self-defeating. While such a strategy might be potentially successful locally in the short run, in the long run such an approach is untenable. Stabilizing attempts at saving a beach usually end up in destroying it. Because of its dynamic character no structures should be allowed on the beach, except for portable accessories to recreation. Groins, seawalls,

riprap, bulkheads, and other beach stabilization measures should not be constructed unless a concentration of urban settlements is already so extensive that it must be protected from the ocean in order to avert substantial economic and human loss. Even in this event an economic analysis should be undertaken in order to discover whether or not the cost of the beach stabilization project is warranted by the amount of capital already invested in the urban area. Other management policies on the beach primarily relate to reducing the conflicts among competing beach users, such as surfers, fishermen, sunbathers, swimmers, and beach vehicles.

b. The Dunes

Primary dunes are formed adjacent to the beach through wind transport of the finer grades of sand and by the growth of vegetation that allows this sand to accumulate in the characteristic dune shape. The dunes are major storage centers for beach sediments and play an important role in absorbing storm waves. Natural dunes are constantly shifting and migrating and move inland along with the shoreline in those areas that are eroding. In some areas there is a secondary dune field that supplements the functions of the primary dune. Where possible these secondary dunes should also be protected. The management implications for the dunes dictate that development should occur neither directly on the dune nor in areas of its probable migration. Setback lines for construction in the dune area should vary according to local environmental characteristics,

and thus no uniform setback standard can be suggested here. A recent aerial photographic review of North Carolina's coastal erosion problem, however, recommended setback lines ranging from 40 to 270 feet depending on location and the desired level of storm protection. Moreover no alteration of the dune surface should be permitted. This would include leveling the dune, building up the dune, introducing exotic plant species, eliminating natural vegetation, or lowering the water table in the dune. Any of these alterations will ultimately affect the beach shape and its capacity to absorb daily as well as storm wave action. In those cases where development is deemed allowable in the dune area, access to the ocean over the dunes should be controlled by requiring boardwalk overpasses for both vehicles and pedestrians.

c. Washovers

Washovers occur where the ocean breaks through the primary dune and carries sand and water onto the spine of the barrier island and sometimes actually all the way over the island to the sound. It has been suggested that this process is a primary means of barrier island migration and enhances the productivity of the marshes in the coastal sounds. Washovers generally occur in those areas where the primary dune system has been weakened--either by natural forces or by man. Roadways constructed perpendicular to the beach have often facilitated storm washover by acting as preconstructed flood channels. Washover areas are particularly susceptible to flood damage and are

also potential sites for inlet formation, and thus development should be discouraged in this area. Fortunately, washover fans should be readily identifiable through soil analysis and aerial photographs. It is impossible to establish a uniform width of washover fans and thus a standard set of dimensions for regulating development in washovers cannot be spelled out here. These areas will have to be defined on a case by case basis by trained personnel. Control of site design should be able to limit storm destruction in washover and nearby areas by minimizing alterations of an area's natural topography, controlling densities, and minimizing impervious surfaces. In particular those buildings that are allowed in such areas should meet the building code standards and be able to withstand high winds and likely flooding. Placement of public utilities and other public improvements in washover areas should be avoided. Roads are particularly susceptible to storm damage and are quite expensive to keep passable and free of sand and water. Where it is impossible to substitute new transportation alternatives in washover areas, roads should be elevated to allow for the natural flow of sand and water.

d. Inlets

Inlets form the dynamic link between the ocean and the coastal sounds. In addition to being subject to longshore currents, sea-level rise, and normal wave action, the inlets are also significantly shaped by twice daily tidal currents. The combined interaction of these currents results in broad, fluctuating fans of sand deposition

on both the sound and ocean side of an inlet. The inlet serves as a migratory route for marine species. It brings in sediments which form a physical substrate for the marshes, aids in widening the barrier island through the delta formations, and also allows the mixing of salt and fresh water that enables the formation of the estuarine-lagoon environment.

The natural importance of inlets cannot be overemphasized and thus dredging, jetties, and other artificial stabilization strategies should be pursued with caution. Tampering with inlet dynamics can endanger the natural functions as well as cause drastic changes in the erosion-deposition patterns in the area surrounding the inlet. In addition, inlet dynamics are also quite hazardous to property owners in such an area. Permanent development should be discouraged within certain distances of inlets; however, these distances will have to be determined on an inlet by inlet basis. While some inlets are relatively stationary from year to year, others are wildly fluctuating. New Inlet, for example, has migrated over a mile during the last quarter century. If development is allowed in inlet areas, it should be permitted only after potential landowners are warned of the risks inherent in developing there. Public investments in inlet areas should be minimized.

Where stabilization of an inlet is deemed essential, it should not be perceived as a permanent solution but instead, should serve to protect existing property for a designated period, such as the

useful life of the structure. Stabilization of inlets to encourage economic activity (new port facilities, navigation, etc.) should be subjected to a thorough environmental impact statement, including a comprehensive cost-benefit analysis. Where new inlets develop they should be allowed to migrate naturally and only be filled when absolutely necessary, and then only after thorough analysis of alternative actions. Where such inlets sever poorly placed road networks, alternative transportation policies, such as bridging and ferry service, should be explored.

e. Aquifers

Aquifers are naturally occurring water bearing bodies of permeable rock, sand, or gravel. The aquifers on the barrier island exist as a shallow lens-shaped body of freshwater floating on saltwater that has intruded into deeper sediments. The extent of this groundwater varies considerably on the barrier island, with the greatest supplies being found in the maritime forest and with lesser pockets of freshwater occurring in the dune system. Because freshwater is a limited resource on the barrier island, communities dependent on aquifers for their water supply should be careful not to build over areas that contain relatively greater amounts of freshwater and thus destroy the vegetation that facilitates recharge of the aquifer. Concentrations of freshwater can be determined generally by referring to United States Geological Survey groundwater maps and specifically through hydrological site analysis. In aquifer areas design criteria for site

development and building construction should be developed to minimize impervious surfaces, particularly paving, and to retain natural drainage patterns and topography. As previously indicated, the groundwater also serves an important role in sustaining vegetation that stabilizes surface sand. Withdrawal of groundwater should be monitored and pollution of aquifers should be minimized.

f. Maritime Forests

The maritime forests that sometimes emerge on the widest portions of North Carolina's barrier islands are different from inland forests because of the adaptations they have had to make to the high winds, salt spray, and sandy soils characteristic of the coastal environment. Thus the maritime forest represents yet another unique component of the barrier island system.

In North Carolina the maritime forest is rare, yet it has historically been important as the site for small enclaves of human settlement. The maritime forest is suitable for such development because it occupies high ground that is relatively safe from flooding and hurricane damage, serves as a welcome retreat from the extremes of temperature and wind found outside the forest, and provides a ready supply of freshwater. In addition the maritime forest acts as a storage place for minerals and assists in stabilizing and building up the barrier island itself through accumulation of organic material.

Unfortunately, because of its relative stability and other attributes the maritime forest is under intense development pressures that threaten the natural and esthetic values these wooded areas provide to man. Extensive dense development in maritime forests has not been compatible with this environment's natural processes because it has led to the cutting of large numbers of trees that has reduced the water holding capacity of the area. In turn, once exposed to wind erosion, deforested relic dunes may become active again and migrate over the remaining maritime forest--as well as over human structures. Heavy pressures on the maritime forest's freshwater table in the form of groundwater extraction, filling of ponds, and septic tank contamination also affect the future usefulness of the maritime forest to man. This is particularly important on barrier islands far from water supplies on the mainland.

Compatible development in maritime forests involves: constructing roadways and public service lines to follow natural contours; developing only high land and avoiding the filling of freshwater ponds; minimizing the number of trees cut so that only those trees that directly interfere with construction are removed; and using only native shrubs for ornamentation and soil stabilization. While the maritime forest can sustain some measure of environmentally sound coastal development, much of the maritime forest will have to be protected if it is to retain its functional integrity.

4. Management Tools and Techniques Applicable to Barrier Islands

The following tools are considered to be most useful for successful management of activities affecting the important ecological processes on the barrier islands. The tools are divided into two lists, the first including those tools that are presently authorized or available in North Carolina, and the second including those tools that clearly require new enabling legislation. The tools within each list are in the same order as in Appendix Two, rather than in order of priority. Immediately after the name of each tool is a reference to the more complete description in Appendix Two. Within the discussion of each tool, an attempt is made to relate it to the specific environments that have been identified as composing the barrier islands.

a. Local Tools and Techniques

(1) Presently Authorized or Available

(a) Acquisition of less than fee interests (Appendix Two, Section I D)--This approach, often being less expensive than fee acquisition, may make public protection of significant land areas more feasible. It will not be useful, however, in areas where the interest purchased causes severe restrictions on the remaining use that the owner can make of the land. In such cases, the owner is giving up so much of the value of the land that the interest (easement) will probably cost nearly the full value of the property. Purchase of easements will be most effective in those situations where a

landowner wants to see his property maintained in a less-than-fully-developed state, while retaining some rights of ownership, or where the locality wishes to purchase very limited rights--for example, rights of public access to beach areas through the private property. There may also be cases where the owner can be persuaded to put his land to profitable uses other than full development if local property taxation policies ensure that such use will be reflected in lower taxes for the owner. Purchase of less than fee interests may be particularly applicable where the easement involves only a very limited use and a very small parcel (such as in the beach access situation).

(b) Fee simple acquisition (Appendix Two, Section I E)--Sectors of the beach environment could be acquired by local authorities for recreation, environmental protection, or other valid public purposes. This approach is unnecessary on beach areas because they can be tightly regulated and substantial portions are already public trust lands. Primary dunes can also be thoroughly regulated under the Shore Protection law. Nevertheless purchase of lands to ensure adequate continued public access to the beaches may become increasingly important. Such access, in combination with regulation of dunes, can encourage use of proper walkways and can prevent pathways through dune vegetation which may eventually become blowout.

Fee purchase of lands might also focus on important aquifer areas (for the protection of public water supplies), and parts of washover fans, dune areas, and inlet lands (to provide public recreation areas) that are not otherwise sufficiently regulated. The obvious problem with acquisition is the great expense of purchasing such prime recreation properties.

(c) Utilities extension (Appendix Two, Section II E)--By carefully setting policies concerning the extension of utilities such as sewerage and water lines, the local government can to some extent influence and guide the location of development. A municipality does not have to extend services beyond its jurisdiction and can generally deny extension on any reasonable economic or public purpose grounds. Thus development may be encouraged in compatible environments through provision of facilities in those areas. However, this technique seems very limited for use on the barrier islands, because much critical land is not within or near municipalities and is not dependent on publicly-owned facilities for sewerage and water. These developments rely on their own pumps and septic tanks, a practice that can become damaging when it proliferates in certain areas. Strict regulations on private water wells and septic tanks, if enforced, will make future development much more dependent

on utility extensions. A well-conceived combination of utility extension policies and standards for septic tanks (and perhaps other private facilities) could be an effective technique for guiding development patterns in a general manner. As a practical matter, development on the barrier islands can be expected to outstep the capability of the localities to provide facilities to serve them. In this situation, regulations governing individual lot facilities can become the precondition which makes subsequent utility extension policies effective.

In easily flooded washover and inlet areas and beaches, where policy demands very little or no development, utility extension policies are not as applicable as regulatory policy, because to extend utilities, unless access is regulated, is to encourage unwanted development. In areas (such as dunes, maritime forests, important aquifers, and perhaps parts of washovers and inlet areas) where development is to be allowed with controls, utility extension policies combined with regulations may aid in guiding development to the most compatible area.

(d) Access to existing facilities (Appendix Two, Section II G)--Controls on access to existing facilities are subject to the same considerations as utilities extension. However, the legality of denying access once utilities are available is

questionable unless particular justification can be shown. This tool could be important in an overall scheme of guiding development, because in order to provide utilities for an area where development is desirable, it may be necessary to run them through areas where a no-development policy prevails. Again, controlling access to utilities will have positive environmental effects only if complemented by regulations on their provision by private methods such as septic tanks and wells.

(e) Interim or temporary development regulations: development moratoria (Appendix Two, Section IV B)--Although not specifically authorized by the North Carolina Legislature, temporary or partial moratoria on development might be appropriate in coastal areas where development pressures are great and pose an identifiable immediate threat to the environment or public health. This tool has some precedent in North Carolina. In 1972, for example, Currituck County instituted a 15 month moratorium on approval of new subdivisions, to allow time for land use planning and replatting of subdivisions. County Sanitarians have also imposed temporary moratoria on new construction in subdivisions where dense septic tank use has led to contamination of private wells within the subdivision. Generally the lifting of such a moratorium is conditional on the availability of an adequate public water supply and a waste treatment facility. Moratoria may also be justifiable

in those localities that have only recently initiated local planning under the impetus of the Coastal Area Management Act and have not had time to formulate an adequate management system for protecting the natural processes of the barrier islands.

(f) Conventional zoning (Appendix Two, Section IV C 1)--Conventional zoning can be used to prevent categories of uses most incompatible with the barrier island environment, and can help guide more intensive uses into environmentally compatible areas. More specifically, regulation of lot size can aid in protection of water supplies by reducing use and ensuring more open space. Similarly, by controlling density and minimum lot size requirements, destruction of sand dunes and vegetation may be somewhat reduced. The potential for damage in washover fans and in areas near inlets can be reduced by zoning techniques designed to ensure very low density development. Traditional zoning, used alone, has some limitations as a tool for conserving the barrier island environments. It is especially inapplicable to areas such as beaches, and perhaps extremely flood prone washover and inlet areas where policy dictates prohibition of development, because zoning large areas for "no use" is of questionable legality in North Carolina.

Furthermore, for areas where development is to be allowed, simply controlling the category of use allowed does not ensure that some developments within that use category will not have detrimental impacts on the environment. Traditional zoning does not address itself to the impact of permitted uses. For example, a high intensity use, such as a motel or condominium, may be permissible or even desirable on a certain part of a barrier island, but only if such impacts as waste disposal are properly handled. More thorough consideration of the environmental characteristics of zones, and better adaption of zoning criteria to those characteristics, can bring some improvement. Another approach is use of so-called flexible zoning techniques which allow project-by-project analysis and approval. Although these techniques are of untested legality in North Carolina, some of them have been used by localities without legal repercussions, and are potentially useful on the barrier islands.

(g) Special exception or special use (Appendix Two, Section IV C 7)--This technique is authorized in North Carolina, but its traditional mode of use must be expanded to protect critical barrier island environments. The legal limits of such expanded use are not certain. The area to be protected must be delineated, and then zoned for a very non-destructive, non-intensive use such as agriculture or very large residential lots. Other specified uses may be permitted in that zone, but

only after each has been presented to the reviewing body for approval. Approval is based on a finding that certain pre-existing (in the ordinance) criteria are met. Conditions may be attached to the permit by the reviewing authority. This technique is limited in its capacity for individual project control by the bounds of reasonableness of the criteria in serving the public health, safety, and welfare, and therefore need only be reasonably related to, among other things, the unique conservation of characteristics of the area in question.

Another application is to require that specific types of development there are considered to have a great impact on the environment be required to obtain a special use permit to locate anywhere within the zoning jurisdiction. This is already done in many North Carolina cities to control location of apartments or certain types of businesses.

Thus the special use permit can be used to provide for flexible, case-by-case analysis for many types of development which might, because of their nature or location, have detrimental environmental impacts. A permit could be required for all uses in such dynamic areas as floodways, washovers and inlet areas to insure that they in no way increase the probability of flood damage. Otherwise, the expanded special use permit requirement could be very effective in dunes, maritime forests, and other areas where development is

allowed but maximum guidance is necessary. In such areas, only intensive uses are required to get a permit, and the legality of the permit requirement, when reasonably applied, is not so tenuous.

(h) Planned unit development (PUD) and cluster or average density zoning (Appendix Two, Section IV D 1)--These two tools can be used either separately or in combination to allow deviation on a project-by-project basis from rigid zoning, and to thus arrange structures, roads, and other development features in a manner least destructive to the surrounding environment. This is done by requiring that plans be approved by the local administering body. In return the administering body can allow the developer flexibility as to densities and other limitations often imposed by conventional zoning or subdivision regulations, thus allowing him an adequate return on his investment. These tools are of course not applicable to areas where development is to be prohibited, but can be effective to compact development into smaller areas to minimize destruction of dunes and vegetation, prevent site and road layouts that might encourage washover or increase damage therefrom, minimize damage from erosion, and reduce coverage of surface area above aquifers. This tool is limited to large, unitary developments.

(i) Subdivision regulations (Appendix Two, Section IV D 2)--Subdivision regulations are applied to control the development of raw land into building sites by ensuring that certain standards are met by including public improvements such as streets, drainage pipes, sewers, and so forth. Subdivision regulation is subject to one important limitation--it is done only once at the planning stage of the subdivision and therefore subsequent attempts at stricter regulation can apply only to land which has not already been subdivided. Much land on the barrier islands has already been subdivided and is therefore exempt from any new criteria in the form of subdivision regulations. For this reason it has been suggested that re-subdivision be required, but the legality of such an approach is not clear.

With the above limitation in mind, this tool is useful in all areas of the barrier islands because it applies to all subdivisions, regardless of location. But on the other side of this coin lies a weakness, because the flexibility of the tool is limited due to the requirement that regulations be uniform for all subdivisions, no matter where located. This uniformity makes it difficult to tailor regulations to the unique characteristics of a particular environment. Nevertheless, the regulations can control some important aspects of the subdivision layout such as placement and design of roads,

setbacks, and open space (either through open space requirements or dedication of land for parks). These controls can be important in:

--aquifer areas; because provision of some open space and control of roads aids in reducing paved areas and helps somewhat in aiding recharge of groundwater with clean rainwater. The prevention of pollution would, of course, be much greater if waste treatment facilities, rather than septic tanks, can be required through subdivision regulations.

--parts of washover fans, generally behind primary dunes; because control of roads is important to ensure that they are not perpendicular to the shore, thereby forming conduits for storm surge.

--dune areas; because control over roads and dedication of open space can allow layouts designed to disturb as few dunes as possible.

Subdivision regulations seem not to be very useful in inlet areas, beaches, and perhaps parts of washover fans, because in those areas prevention of development is desired.

When subdivision regulations are combined with other tools, the effect can be greater control, or perhaps prevention, of development. For example, mandatory dedication of land or capital facilities may be attempted. Controls relating to

off-site facilities also have potential for controlling the location of development, by requiring that all development connect to sewer and water lines and then controlling the extension of such lines. However, the legality of these techniques is questionable.

(j) Building inspection (Appendix Two, Section IV H)--Implementation of building codes, or adoption of stricter standards where codes already exist, might aid in minimizing storm and flood damage. This entails requiring more wind-resistant construction and requiring that structures either be on high ground or elevated by pilings so that they are safely above potential flood levels. Such standards, though certainly not guaranteeing prevention, would be effective in reducing flood damage in washover fans and near inlets, as well as reducing storm damage in all unsheltered areas on the barrier island.

(k) Regulation of mobile homes (Appendix Two, Section IV I)--This technique should be applied to ensure that mobile homes are located only in the most compatible areas of the barrier islands. Mobile homes should not be allowed in washover fans and inlet areas because of the near certainty of destruction by any flooding. The same is true in areas unprotected from high winds. This leaves maritime forests or other areas with fairly stabilized vegetation as the desirable sites for

mobile homes. Even in those areas density control, perhaps through septic tank regulations and zoning, should be applied to protect aquifers, dune vegetation, and nearby waters, due to the potential of mobile homes for extremely high density and their reliance on septic tanks.

There is good legal authority in North Carolina allowing local use of the zoning authority to require that mobile homes be restricted to non-residential districts, and perhaps to only those areas zoned for mobile home parks. This gives local government the capacity to restrict mobile homes to only those areas of barrier islands that are most compatible with their use. This authority should be exercised.

(1) Sand dune protection ordinances (Appendix Two, Section V A 2)--The Sand Dune Protection Act enables coastal counties to establish a shore protection line on the barrier islands. Thereafter, all persons who propose to alter or destroy any sand dunes oceanward from that line must receive a permit from the county. This tool therefore allows thorough control of all forms of development on the beach and dunes near the beach. Thus far this regulation has been applied to a limited area from the rear of the primary dunes oceanward. This is a narrow interpretation of the boundaries of the shore area, and it seems clear that at least some secondary dune areas can be included. Shore protection is therefore a very

effective regulatory tool for all beaches, primary dunes, and probably secondary dunes areas. The line must be drawn somewhere, and whether the line may incorporate maritime forests or aquifer areas is not totally clear. There is, however, strong authority that such areas may be included. At least one county has done so. Controlling alteration of barrier dunes is also very important in proper management of washover fans, because destruction of barrier dunes enhances washover, and artificial stabilization encourages development and therefore greater potential property loss from a storm surge great enough to break through the barrier dunes. The shore protection tool can be very effective in controlling development that faces possible destruction because it is too close to inlets. Regulation through shore protection has high potential effectiveness for conserving dunes and beaches and all other areas covered because it grants authority to regulate removal of materials and vegetation, and operation of vehicles within the areas. These are powers arguably not granted under other clearly authorized regulatory techniques.

(m) Local health regulations (Appendix Two, Section V A 1)--Local health departments are authorized to provide and administer health services and to enforce State health laws. On the barrier islands local health department's powers to enforce septic tank and water supply regulations are particularly

important in ensuring that groundwater supplies are not contaminated. (See also "Regulation of Septic Tanks" in Appendix Two, Section V B 7.) While localities may not weaken State health regulations, they may adopt stronger requirements for certain health problems. In several coastal localities, for example, septic tank regulations are more stringent than the State standard. These stricter standards reflect the special problem that large, dense settlements, dependent on septic tanks operating on sandy, porous soils, pose in the coastal environment.

(2) Techniques not yet Authorized

(a) Transferrable development rights (Appendix Two, Section I D)--The basic concept underlying transfer of development rights is that ownership of land gives the owner a bundle of rights, each of which may be separated from the rest and transferred to someone else. The right to develop the land is one of these rights. Under a transfer of development rights system, an owner can sell this development right to another property owner who is required by statute to collect a specified number of development rights before developing his or her own property.

Under a typical transfer of development rights system, the government awards development rights to each parcel of developable land in the community based on acreage or value

of the land. The system is set up so that no owner possesses enough development rights to develop all of his or her property without buying some rights from someone else. Persons sell their development rights on the open market because they do not want to develop or are prohibited by some regulation from developing.

This technique offers a theoretically sound approach to overcoming the problem of compensating those landowners whose property will be greatly diminished in value due to new regulations restricting its use. At any point in time there will be many landowners who purchased property before it was subject to those regulations, and any method of avoiding such unanticipated losses appeals to a sense of fairness and eliminates the possibility of the regulation being adjudged an unlawful "taking" as related to such properties.

However, such a system faces legal problems, as well as practical hurdles of a magnitude related to the amount of property to which it is applied, because a new system for zoning land and transferring and recording development rights would be required. New enabling legislation is also clearly required.

Perhaps such a system might be feasible just for the barrier islands. This would require awarding development rights to landowners in downzoned aquifer, inlet, dune and

washover areas which could be redeemed in the right to develop equivalently in areas more compatible with development. Such a limited system might not be an unreasonable burden.

(b) Compensable regulation (Appendix Two, Section I G)--This technique is an attempt to compensate owners for losses in property value due to new regulations. The diminished value is paid to the owner in the amount by which the value of the land at the time the regulation is applied exceeds the value after it is applied. This clearly avoids "takings" problems. It entails staggering governmental expenditures for compensation where conservation policy entails stiff regulation, or where regulations cover vast areas of land.

Compensable regulation seems financially feasible only if a method is developed to determine a permissible level of regulation for any tract of land. This would entail a rational formula for balancing the reduction of the value of a parcel of land with the public purpose served by the regulation that causes that reduction. An affected landowner would only be compensated if the value of his land sank below the permissible level, and then only for the difference between the permissible level and the reduced value of the land. (This would be a formula for the familiar "taking" issue.) The setting of such a permissible level of diminution of

value through regulation would not be simple, and would probably encounter legal obstacles without authorizing legislation. But it does not seem impossible.

(c) Property taxation: preferential assessment (Appendix Two, Section III E)--This technique seeks to discourage development of certain chosen classifications of land by allowing that property within such classification be taxed at a lower rate. The object is to reduce the ultimate tax bill, thereby reducing the financial pressure on the owner to sell property. The value for developable land on the barrier islands is so high that consideration of changes in tax rates is not likely to be determinative in the owner's decision as to what use to make of the land. In fact, recent studies show that preferential assessment in areas of rising land values tends more to encourage speculation than to significantly retard development. Thus, the technique is likely to produce desired results only in exceptional cases. Furthermore, new legislation is required to implement preferential taxation for a new class or classes of land.

Another more feasible method of achieving the result of reduced taxation of certain lands under existing law is simply to require that assessment practices consider the effect of regulations in determining the value of such lands, thereby reaching a reduced value. This approach of course assumes the existence of limiting regulations, and it is

primarily those regulations rather than reduced taxes that protect the environment. Nevertheless, this approach to valuation of land for tax purposes is presently available with little extra administrative difficulty, and is equitable. Thus any desirable results will probably represent a new gain. The same cannot be said for preferential assessment, because the questionable utility may be outweighed by the trouble required to pass new legislation.

Neither approach provides adequate control in areas where severe restriction on prohibition of development is called for. However, in dunes, maritime forests, and aquifer areas where development is allowed, lower taxation may be of some marginal impact. Lower assessment might therefore be applied, in addition to a well-devised regulatory scheme.

(d) Bonus and incentive zoning (Appendix Two, Section IV C 11) --Bonus and incentive zoning allow the community to obtain certain amenities from a developer or builder in exchange for certain agreed upon concessions. This tool, though probably not authorized per se in North Carolina, could probably be effected by use with PUD and cluster zoning ordinances. Bonuses such as allowing increased density of development can be exchanged for such desirable site development features as retaining or replacing vegetation and dunes, providing waste treatment facilities other than septic tanks, building on

pilings to decrease danger from flooding and to allow natural sand movement, and providing board walks for access to beaches.

(e) Performance zoning and performance controls for sensitive lands (Appendix Two, Section IV C 13)--This technique focuses on allowing development based on its impact on a chosen ecological characteristic--such as groundwater quality. Although this technique theoretically goes to the heart of protecting environmentally sensitive areas, it requires a level of technical expertise in setting standards and measuring impacts that is presently impracticable for most local governments. Less specific tools are therefore called for at the present time. However, where impacts on the environment can be reasonably and practically measured, this technique should be employed in whatever form will most enhance legal acceptability (performance zoning per se is not clearly allowed under North Carolina zoning enabling legislation and special legislation is probably required). As techniques for impact measurement advance, the effectiveness of this technique will increase. At the present time, simpler applications could be used to protect the barrier island environment. Standards could be established for: destruction of vegetation in dunes and maritime forests; permissible area of paved surfaces in aquifer areas; alteration and removal of sand from sand dunes and beaches.

b. State and Federal Tools and Techniques

(1) Areas of environmental concern (Appendix Two, Section VI)--The North Carolina Coastal Area Management Act specifies that five of the six component environments of the barrier islands may be designated as areas of environmental concern (AEC) in which all persons seeking to develop in those areas must first obtain a permit following the procedures established in the Coastal Area Management Act (N.C.G.S. 113A--118 to 123). Although maritime forests are not specifically eligible to be designated as an AEC, portions of the maritime forest that fall into other eligible AEC categories, such as aquifer areas, areas that sustain remnant species, and unique natural areas, may be protected by the area of environmental concern permit system.

If all six of the component environments are designated, then the entire barrier island can be regulated under the AEC development permit system, allowing case-by-case decisions concerning approval of all new development. This would be a very thorough and powerful regulatory capability, but would entail a great increase in administrative responsibilities for the local governments. Where a local government is not capable of handling project-by-project analysis of all minor developments, other tools which are more administratively feasible should be used to complement the AEC development permit system.

If maritime forests, or any other environments, are not designated, the volume of the permits, and thus the administrative burden, will be reduced. It may therefore be feasible for local governments to use the AEC permit as the comprehensive management tool within these environments. Nevertheless, it will still be important to employ other management tools in the areas not within, but in proximity to, the AEC's. This is because the environments interact through the dynamic processes at work on the barrier islands, and sound management of one area requires complimentary management of those areas with which it interacts.

(2) National Environmental Policy Act (Appendix Two, Section V C 1)--The National Environmental Policy Act mandates that all major federal actions significantly affecting the quality of the human environment must be accompanied by a detailed environmental impact statement. On the barrier islands this tool can be an effective vehicle for allowing the public and local governments to participate in evaluating the environmental effects of federal beach stabilization and navigation projects, highway projects, as well as other federal activities.

(3) National Flood Insurance Program (Appendix Two, Section V C 2) --This federal program provides insurance at a subsidized rate to communities in flood hazard areas where private insurance is either unavailable or unaffordable. To be eligible coastal localities must adopt certain minimal land use controls so as to minimize the probability of flood damage.

There are several other state and federal tools which may have some impact, though probably slight, on the barrier islands. State tools include regulation of public drinking water supplies (Appendix Two, Section V B 1), mosquito control (Appendix Two, Section V B 2), regulation of solid waste disposal sites (Appendix Two, Section V B 4), regulation of construction of water wells (Appendix Two, Section V B 6), regulation of septic tank with a capacity of over 3,000 gallons (Appendix Two, Section V B 7), control of coastal wetland activities (Appendix Two, Section V B 13), dredge and fill permits (Appendix Two, Section V B 14), and regulation of water capacity use areas (Appendix Two, Section V B 15).

Federal tools are regulation of bridges over navigable waterways (Appendix Two, Section V C 5), and permits for dredge and fill and for structures other than bridges in or over navigable waterways (Appendix Two, Section V C 6).

B. The Lagoon-Estuary System

The lagoon-estuary system is comprised of the following environments:

--Mid Salinity System

--Mud and Sand Flats

--Salt Marshes

--Swamp Forests

The processes, policy implications, and applicable tools for each environment are presented separately. Before discussing each environment,

however, the processes involved in the overall lagoon-estuary system are briefly summarized.

In the lagoon-estuary system, one group of processes stems from the mixing of the fresh water from surface runoff, rivers and streams with the salt water from the ocean. This mixing area allows for the exchange of fresh water-borne and ocean-borne materials necessary for plant production and the habitat requirements of a variety of organisms. The river supplies freshwater, nutrients, sediments and potential pollutants while the ocean supplies organisms and salts. The quantity of these materials is dependent on the volume relationship of fresh and salt water. If the freshwater inflow from the streams is greater than that from the ocean, then a greater amount of nutrients, sediment and other materials from inland river systems will be present in the lagoon and estuary. If the amount of inland nutrients, sediments and other pollutants increase, in relation to ocean borne materials, the possibility of overnourishment or eutrophication also increases.

Another process involved in the mixing of river and ocean waters is the variation in salinity or the amount of salt in the water. Salinity varies daily due to the influence of the lunar tides and regionally and seasonally due to the variation in freshwater inputs from inland streams. The value of this variation in salinity is it provides a habitat for species requiring salinity changes to survive and for species that can tolerate wide salinity changes.

Although not as prevalent in North Carolina lagoons and estuaries, the meeting point for fresh water and salt water generally has a two-layered system of circulation. The bottom layer is saltwater providing a pathway for larval and juvenile animals to move upstream to continue their life cycles. The top is a layer of fresh water providing a pathway for adults and older juveniles to move downstream and out to sea. This layering effect is not found extensively in North Carolina because the lagoons and estuaries are shallow enough for the wind to keep well mixed. However at the points where this two-layered circulation system occurs, it provides the pathways for migration and spawning essential to the propagation of the life cycles of many fishes, shellfish, and crabs.

Variation in productivity is another characteristic of the lagoon-estuary system. Generally the plant production is dependent on the intensity and duration of sunlight, the temperature of the water and the amounts of nutrients, especially nitrogen, a known limiting factor, that are available. Since lagoons, sounds, estuaries, salt marshes, mud and sand flats each have a slightly different set of values for the productivity parameter, each has a different average productivity. In addition since the parameters vary regionally and seasonally so that no two salt marshes have the exact same productivity and no salt marsh has the same productivity year round. The value of productivity is that the higher trophic levels of the food chain are dependent on the amount of plant production as a source of food. Thus a decrease in primary plant production could have serious repercussions along the food chain.

An important process to the lagoon-estuary system is the flooding of the estuary which usually occurs twice daily. Flooding the estuary allows the exchange of particles from the sea in return for nutrients from the inland streams. Marsh plants convert these nutrients along with sunlight into plant tissue in the process of photosynthesis. These nutrients are also essential to plankton and other primary producers which are the crucial link in the food chain for upper trophic levels such as spawning and migrating fishes, shellfish and crabs.

Equally important is the process whereby the estuary is flushed, usually twice a day. In the process of flushing the estuary, chemicals and organic materials that have accumulated in the marsh from the decomposition of plant tissue by bacteria are released into the estuary. These materials primarily in the form of detritus or organic substance are a major food source for shellfish, zooplankton, migrating and spawning fishes and crabs. In addition the chemicals that are released are a major nutrient source for phytoplankton important in primary production.

Nutrient storage is a process that occurs in mud and sand flats, marshes, and swamps. It is the process by which nutrients, chemicals and toxic substances are filtered out of the water and concentrated in vegetation and soil and either taken up by the plants or chemically bound to soil particles. The presence of these large pools of materials stored in swamps, marshes and flats buffers the concentration of materials in the water against very high and very low amounts. Thus the inflow of nutrients to the estuary is kept at an equilibrium or stable level.

As water flows into the estuary from the upland streams, it is slowed by means of swamp and marsh vegetation thus reducing erosion of the uplands and sedimentation of the estuary which can increase turbidity and reduce productivity. In the reverse direction, as the tides and storm waters flood the estuary, the water is slowed by means of marsh and swamp vegetation thus protecting the upstream areas from storm and flood damage.

The vegetation along with the soil of marshes and swamps also filter incoming and outgoing water in such a way that the sediments settle out and are stabilized by new vegetation growth. The value of this sediment trap is that it reduces sedimentation of the estuary and thus decreases the turbidity that can inhibit high productivity.

In swamps, the valuable process of water table maintenance occurs. It involves the recharge of groundwater when stream levels are high to make up for groundwater lost during dry periods. By recharging or increasing the groundwater head, saltwater intrusion of the deep water supply aquifers is retarded.

The productivity in swamp forests is limited by the acidity of the peat soils which inhibits the soil processes necessary for nutrient uptake. Also the availability of nutrient necessary for photosynthesis is reduced and the soils are low in essential nutrients. Because of these three factors only plants that are suited to wet climates, including pond pine, cypress, gum and evergreen shrubs can survive in swamps. These plants are important in providing a unique habitat for many small fur-bearing animals, ducks, birds, black bear, bobcat, deer and fish.

All the processes discussed above are inherent to the lagoon-estuary system, although occuring to different degrees in the individual environments which make up that system. These environments are discussed in more detail in the sections which follow.

1. Mid-Salinity System

a. Ecological Processes

The mid-salinity system includes the open water areas of the estuaries and lagoons where mixing of fresh water with oceanic waters creates an environment unique from the low salinity riverine systems upstream and the higher salinity coastal waters seaward. There are four key processes essential to the maintenance of the productivity of the mid-salinity system: the volume of fresh water input; the quality of fresh water input; the temperature of the system; and the slow movement of water through the system. The system will tolerate some variation in each of the elements, though rarely without suffering some attendant decrease in productivity.

The volume of fresh water input is important for a number of reasons. The estuary itself does not produce enough primary nutrients to sustain its high degree of productivity, but depends upon the flushing of nutrients from neighboring marshes which are flooded during high tides. The estuary also depends on the fresh water input to maintain the moderate level of salinity by which it is characterized and which makes it so productive. The tides provide a fairly constant supply of salt water, but because of the broad,

shallow nature of the estuaries and sounds, a few fresh water sources can lower the salinity of very large water areas. Conversely, restricting water flow will decrease the mid-salinity areas rapidly. Finally, the pressure of the fresh water flow aids in the flushing of the estuary at low tide, a process which is extremely important to organisms which need to migrate seaward as they mature.

The quality of the fresh water which flows into the estuary is perhaps the most vulnerable element of the mid-salinity system. The fertility of the system is dependent upon the concentration of nutrients in that water, and is easily threatened by an increase in many types of pollutants. Pollutants of all forms may be tolerated to some degree, but even at low levels, many types may make the resident organisms unfit for human consumption, and prevent the annual return of certain migrating organisms.

The system will allow variations in temperature over a fairly broad range, but it is important that those changes not be rapid. Resident organisms tend to be slow-moving, but can adapt to slow changes in temperature by changes in their metabolism or by migrating to a more desirable location. Migrating fish require some long-term stability in temperature, as that is one of the "clues" they use to identify the stream in which they will spawn.

The final process essential to the system is the slow movement of water through it. The broad flat nature of the system and the constant pressure of the tides slows the loss of fresh water and allows

the settling out of mineral and nutrient-rich sediments. These bottom sediments provide a constant source of food for estuarine organisms.

b. Destructive Human Activities in the Mid-Salinity System

Human activities which adversely affect the estuary include changing its physical shape, and using it as a dumping ground for some type of pollutant. The tools and techniques which can be used to protect the natural processes of the estuary are all environmental regulatory tools, and because of the interjurisdictional nature of the pollution problem, the tools usually must be applied at a level of government above the county, although counties may participate in the enforcement process.

The basic human activities which affect the environment are the following:

(1) Upstream Perturbations in Watercourses

(a) channelization

(b) upstream damming, flood control and water diversion

(2) Perturbation in Estuary Shape

(3) Perturbations in Water Quality

(a) industrial pollution

(b) agricultural and urban pollution

(c) thermal pollution

The policy implications and applicable management techniques are discussed directly for each of these process disturbing activities.

The discussion of specific destructive human activities and management tools applicable to them is preceded by a discussion of the general statutes and common law doctrines by which local governments may enforce environmental regulations.

(1) Upstream Perturbations in Watercourse

There are two principal types of upstream perturbations: (a) channelization, which changes the speed and to some extent the quality of the water which passes through the mid-salinity system; and (b) activities such as damming and flood control measures, which may substantially decrease water flow.

These perturbations offer no benefits to the mid-salinity system or the organisms in it. A decrease in the volume of fresh water input is perhaps the least detrimental perturbation, because so long as the water is not heavily polluted it will merely decrease the size of the system and except in extreme cases, productivity can be increased again if the water flow is increased. Where the water introduced into the mid-salinity system is polluted, however, upstream activities become much more dangerous and threaten not just to decrease productivity, but to eliminate it by destroying local organisms and averting those organisms which come there to spawn.

(a) Channelization

Channelization of streams above the estuary will tend to decrease the productivity of the system. Channelization causes erratic fluctuations in the volume of fresh water

input, introduces pollutants in intermittent pulses, and increases siltation within the estuary. This will tend to destroy the benthic (oysters, mussels, clams) habitat and decrease the spawning area of anadromous fish. Because some fish will spawn only in their home stream, destruction of that habitat will eliminate the stream from any future fish usage. Channelization is particularly harmful to the system because it is difficult and often impossible to return the watercourse to its original state.

Management Tools and Techniques Applicable--Where channelization upstream has substantially affected water quality in the estuary, an affected party may seek to have enforced the Water and Air Resources Management Act (G.S. 143-211 et seq.) which empowers the Environmental Management Commission to administer a program of water pollution abatement to prevent damage to public and private property, and to prevent injury to plant and animal life. Under that Act the EMC is empowered to establish water quality standards for each stream and has broad powers to enforce those standards. Whether the watercourse can be returned to its former state will depend upon the specific circumstances in each case.

(b) Upstream Damming, Flood Control and Water Diversion

Any activity upstream which reduces the volume of fresh water flow into the estuary will have a substantial negative impact on the productivity of the system. The system depends

upon a fresh water-salt water balance, and a decrease in fresh water input will increase the salinity of the estuary and decrease the water area which can be characterised as mid-salinity. Given a steady rate of influx of pollutants, the decreased water flow will increase the concentration of pollutants, while at the same time, that decreased flow will tend to bring fewer nutrients into the estuary from neighboring swamps and marshes.

Management Tools and Techniques Applicable--

i. Where the diversion of water from a stream has decreased the productivity or size of an estuary, an affected party has at least two remedies available:

--He may petition the EMC for the designation of a Capacity Use Area under the general provisions of G.S. 143-215.13, in which case the EMC may regulate the withdrawal of water for the protection of both public and private interests (see Appendix Two, Section V B 15).

--He may petition the EMC for a hearing on an area in which the EMC has reason to believe that the withdrawal of water is having an unreasonably adverse affect on those waters (G.S. 143-215.13(d)). The EMC may then prohibit or regulate the withdrawal of substantial amounts of that water.

ii. Where the loss of fresh water flow is due to an upstream dam, the injured party may petition the Secretary DNER to enforce the Dam Safety Law (§143-215 1.23 et seq.) which recognizes the importance of ensuring maintenance of stream flows below such dams of adequate quality and quantity (G.S. 143-215.24). DNER and the EMC are empowered to investigate complaints and require those steps which would alleviate the injurious condition (§143-215.32) (see Appendix Two, Section V B 16).

(2) Local Perturbations in Estuary Shape

Changes in the shoreline (bulkheading and filling) or floor (dredging) of the estuary will usually have a detrimental effect on the system. Changing the floor of the estuary by dredging may increase the volume of the tidal exchange and reduce the available food sources and plant cover. Bulkheading and filling along the shorelines will generally decrease the productivity of the system by denying juvenile organisms access to marsh areas while they seek protection and food in their early stages. These activities may also have some very deleterious short-term effects in that they tend to increase sedimentation in the system.

Clearly, perturbations in estuary shape should be kept to an absolute minimum, as they offer no benefit to the system. Where dredging, filling or bulkheading are determined to be desirable for some other reason, it should be recognized that a proportionate loss in productivity is likely to result.

Bulkheading is generally less damaging to the system than dredging or filling, as it will not usually increase the level of sedimentation to as great an extent. Because the sedimentation may permanently destroy benthic habitats without significantly inhibiting the cycles of migrating anadromous fish, care should be taken to dredge or fill only where the productivity of the benthic organisms can be or has been sacrificed, or where it is possible to dredge without stirring up large amounts of sediment.

Management Tools and Techniques Applicable--

i. The primary control over this type of activity is the Dredge and Fill permit system administered by the Marine Fisheries Commission under G.S. 113-229. A permit must be obtained before any person may excavate or fill any marshland, tideland, or estuarine area. Once the permit has been issued, however, it is challengeable only on procedural grounds, as a rule, so it is important that objections be filed with the Marine Fisheries Commission before the permit letting process is complete (see Appendix Two, Section V B 14).

ii. Where the state permit has been issued these activities may be prevented by petitioning the Army Corps of Engineers. Under 33 U.S.C. 403, a permit from the Corps must be obtained before dredging, filling or bulkheading may take place in

navigable waters. The Corps does not automatically approve permits on the basis of state approval (see Appendix Two, Section V C 6).

iii. Where bulkheading, dredging or filling has had a substantial adverse effect on water quality in the estuary, an affected party may seek to have the Environmental Management Commission enforce the general mandate of the Water and Air Resources Management Act (143-211 et seq.) and the regulations promulgated under it. Because there is already established a rigorous procedure for obtaining permits to dredge and fill, the outcome of that process will probably carry a great deal of weight with the EMC and the courts as well. Thus, this broad statute should be used only where the permit process has clearly failed to protect the estuary.

iv. An affected party may also petition or file suit against the EPA for the enforcement of the Water Pollution Prevention and Control Act of 1972, (33 U.S.C. 1251 et seq.) but the federal government also has a dredge and fill permit process, so use of this statute should be limited to those conditions discussed above.

(3) Perturbations in Water Quality

There are three major types of perturbations in water quality: (a) industrial pollution; (b) agricultural and urban pollution; and (c) thermal pollution. The pollutants generally enter the water

well above the estuary from point sources such as private and municipal sewage plants, industrial plants, etc., although substantial amounts of pollutants enter the water from non-point sources.

The introduction of "pollutants" into the estuary may offer some benefit to the system. Increased water temperature may extend the growing season of the inhabitants and an increase in the level of organic nutrients from some urban wastes and agricultural runoff may improve the fertility of the system. These factors are of less value to the system, however, to the extent that they are open to rapid change (increase or decrease) and careful monitoring should be enforced.

Activities which introduce pesticides, herbicides or metallic pollutants should be strictly controlled and allowed only where, as a matter of policy, it is determined that the organisms which inhabit the system are expendable.

(a) Industrial Pollutants

Industrial wastes (from pulp and textile mills, mines, e.g.) offer no benefits to the system. Small increases in the amounts of certain metallic pollutants (copper, mercury, zinc) or any substantial amount of pertoleum based chemicals are likely to have a detrimental effect on the system's inhabitants. High levels of these pollutants are toxic to adults, but lower levels can inhibit the reproductive functions

of the organisms and the mortality rates of the juveniles. Further, many of the organisms tend to accumulate pollutants to such a degree that they become unfit for human consumption. Industrial pollutants may change the chemistry of the water to such a degree that migrating organisms which depend upon the estuary as a spawning area will avoid it.

Management Tools and Techniques Applicable--

i. When the pollutant appears to be a petroleum product there may be any number of polluting sources and there are a large number of statutes which would control that pollution.

--The most direct route would be to petition the Secretary of DNER for enforcement of G.S. 143-215.76, which prohibits the discharge of oil by-products into state waters. The Environmental Management Commission has extensive powers of investigation and may assess stringent penalties (§143-215.84, 143-215.90, 143-215.91). (See Appendix Two, Section V B 18.)

--Where the source of the pollution can be traced to an oil or gas well, the Secretary of DNER may be petitioned for enforcement of G.S. 113-378 which authorizes the Secretary to regulate such wells to prevent pollution of state waters (see Appendix Two, Section V B 20).

--The Secretary of DNER may also be petitioned for enforcement of general water pollution statutes G.S. 143-215.2 and 143-215.3 (12).

ii. Where the pollution can be traced to a mining operation, an action may be brought by an affected individual or the governmental body involved against the Secretary of DNER for failure to use the authority granted under the Mining Act of 1971 (G.S. 74-51 et seq.; see Appendix Two, Section V B 19). The Secretary has the authority to deny or revoke permits where a mining operation has an unduly adverse effect on estuarine fishing, surface water quality, or where there is sufficient evidence that the operation will result in substantial deposit of sediment in stream beds or lakes, or in acid water pollution.

iii. Regardless of the source of the pollutant, an affected party may petition the Environmental Management Commission for enforcement of G.S. 143-215, which prohibits direct or indirect discharge of waste material into state waters in violation of water quality and effluent standards set by the Commission (see Appendix Two, Section V B 3).

(b) Agricultural and Urban Pollution

The introduction of pollutants into the fresh water supply is not necessarily detrimental to the productivity of the system. In small quantities, untreated wastes from urban areas and inadequate septic tanks or agricultural (fertilizer) runoff may increase the fertility and productivity of the system. But the chance for increased fertility may very often be outweighed by the danger of an overabundance of the pollutants, which can lead to the eutrophication of the system, and the accumulation of toxic substances in shellfish. Agricultural runoff presents the more serious danger of increased levels of pesticides and herbicides which offer no beneficial effects.

Management Tools and Techniques Applicable--

i. Where the pollution is found to be a pesticide or herbicide, a complaint may be brought against the Secretary of the Department of Agriculture, who through the Pesticide Board is responsible for the administration and enforcement of the North Carolina Pesticide law, G.S. 143-434 et seq. Although it can be expected to be extremely difficult to trace the source of the pesticide pollution under most circumstances, where a violator can be found, heavy penalties may be assessed (see Appendix Two, Section V B 10).

ii. Where the pollutant is found to be insufficiently treated animal waste, a complaint may be brought against the Secretary of DNER to enforce G.S. 143-214.2, which prohibits the discharge of biological wastes into state waters, and G.S. 143-215.1(a) which empowers the EMC to control those discharges through a permit system. Under §143-215.2 the Secretary of DNER may issue an order to cease the polluting activity following a hearing, and under §143-215.3(12) he may issue such an order without a hearing where he finds that conditions are imminently dangerous to public welfare, which includes the protection of fish and wildlife.

iii. Where the pollutant is found to be sedimentation from agricultural runoff, the Sedimentation Pollution Control Act will not apply because of a specific exemption in that act. The Secretary of DNER may be petitioned for enforcement of the general provisions of the Water and Air Resources Act (G.S. 143.211 et seq.) perhaps, under the argument that the lack of water purity due to the sediment content threatens the plant and animal life which that Act seeks to protect.

iv. Where the pollution source appears to be individual or municipal septic tanks, an affected party should attempt to contact the health department of the jurisdiction

in which the violation is occurring (see Appendix Two, Section V A 1). If assistance is not provided there, an affected party may petition the Environmental Management Commission for enforcement of the general provisions of the Water and Air Resources Management Act (G.S. 143-211 et seq.)

(c) Thermal Pollution

Thermal and nuclear plants threaten the system not only with radioactive wastes, but also with occasionally drastic thermal change (plant shutdowns). While a slight increase in temperature may increase productivity due to a longer growing season, the entrainment and passage through a plant by anadromous fish larvae is likely to result in heavy mortalities.

Management Tools and Techniques Applicable--

i. Where an affected party finds that the detrimental environmental effects are resulting from thermal pollution of the state waters, that person may petition the Secretary of DNER for enforcement of G.S. 143-214.2 which allows thermal discharge only subject to the approval of the EMC.

ii. An affected person may also request EPA enforcement of 33 U.S.C. 1326 which authorizes the limitation of effluent thermal discharges to assure the protection and propagation of fish, shellfish and wildlife.

c. Enforcement of Environmental Regulations

(1) At the Local Level

Individuals and private or municipal corporations which are adversely affected by pollution of the estuary may choose from a number of options in an attempt to remedy the situation. At both the state and federal level there are pollution control and abatement laws, and there are specific administrative agencies to enforce those laws. For practical and often legal reasons, it is usually best to pursue the administrative remedy first. Filing suit is costly and time-consuming, although some federal statutes allow for very heavy fines and the awarding of court costs and attorneys' fees in the proper situation.

(2) At the State Level

When confronted with a pollution problem in an estuary, an affected party should first approach the Environmental Management Commission in the Department of Natural and Economic Resources. The EMC is charged with the promulgation and enforcement of rules and regulations for the protection, preservation and enhancement of water and air resources of the State (G.S. 143B-282). There are a number of statutes which refer to the control of specific types of pollutants (e.g., Oil Pollution, G.S. 143-215.76; The Mining Act, G.S. 74-51 et seq.; etc.) and a complaint may be based on them where appropriate. But under the Water and Air Resources Management Act (G.S. 143-211 et seq.) the EMC is

generally charged with the prevention and abatement of water pollution for the protection of human health, prevention of injury to plant and animal life, and the prevention of damage to public and private property, so it appears that a complaint to the EMC could be based on this statute for any substantially adverse change in water quality.

An affected party need not necessarily know the specific type of pollutant involved, or its source, in order to make a complaint. The EMC has broad investigatory and monitoring powers, and now has at hand the Water Quality Management Plans for each river basin and sub-basin in the state. These plans contain: the stream classifications as to the purpose of each segment of the state's waters; point sources of pollution mapped and described in detail with respect to the location, size, nature and frequency of the discharge; and the testing and monitoring of programs in effect in each area. This information is freely available, and should be equally useful to the affected party who files suit to require enforcement of water quality standards. Where the EMC finds a violation of its standards, it has broad powers to issue stop orders, require the direct and immediate alleviation of the pollution, require payment for damage to fish and wildlife affected, and to levy civil and criminal penalties on violators.

Should the EMC fail to take action within a reasonable time, or settle the matter in such a way that the pollution is not properly abated, an affected party may seek a number of alternative remedies. Under G.S. 150A-43 a person who is aggrieved by a final agency decision and who has exhausted all administrative remedies (appeals procedures within the agency) is entitled to judicial review of that administrative action. In the case of unreasonable delay in deciding or action upon a complaint to the agency a person whose rights are affected by that delay may seek a court order compelling the termination of that delay under G.S. 150A-44. The procedures to be followed in seeking judicial review, and the scope of that review in either case, can be found in G.S. 150A-45 to 150A-51. At least one North Carolina case has indicated that the statute will be construed liberally in favor of the aggrieved person.

An aggrieved party may also have a common law tort action for private or public nuisance against the polluter, where the pollution source is known. To bring suit for a private nuisance an affected party must have a legal interest in some affected land (e.g., oyster beds owned or leased from the state, or perhaps, land abutting the estuary). For affected persons who do not have a sufficient interest in land, the more restrictive theory of public nuisance may be used to file suit.

A public nuisance is an unreasonable invasion of a right held in common by the public. Any public official may sue to uphold the public rights, and a private citizen may sue on the grounds that he has suffered special damages (as opposed to those suffered by the public in general) as a result of the pollution; or he has suffered substantial injury due to the pollution (see Hampton v. North Carolina Pulp Co., 223 N.C. 535, 27 S.E.2d 538 (1943)). Citizen groups will not be able to bring suit under the public nuisance doctrine unless they can fit under one of these tests, but commercial fishermen would appear to have been sufficiently affected to bring suit.

Having shown that he is a proper plaintiff, the affected party will then have to show that the pollution was the result of a negligent, international or ultra-hazardous activity by the polluter, and that the polluting activity was unreasonable in light of the circumstances. Evidence with regard to the causation of the pollution should be available from DNER's Water Quality Management Plans. The costs of the suit can be expected to be substantial, and there is no statutory provision for awarding court costs or attorneys' fees in addition to any money damages awarded.

(3) At the Federal Level

Should an affected party fail to get assistance from the state authorities, he may turn to the federal system by filing a complaint with the Environmental Protection Agency. Under

the Water Pollution Prevention and Control Act of 1972 (33 U.S.C. 1251 et seq.), the EPA is responsible for the enforcement of federal water quality standards. Under that Act the EPA is charged with attaining a standard of water quality suitable to the propagation of fish and wildlife, and so it would seem that a complaint to the EPA for enforcement of the Act could be based upon that statute whenever there is a substantially adverse change in water quality in the estuary. If after sixty days the EPA has failed to have the pollution abated, or to take substantial action toward its abatement, an affected party may bring suit against the EPA for enforcement of water quality standards, and against the polluter directly.

The federal forum is particularly attractive to individual or institutional litigants, as it requires little to show that a party has been sufficiently adversely affected to bring suit. The Act specifically states that any citizen may commence a civil action against any other person (including the United States or any governmental instrumentality or agency) for the violation of an effluent standard. Recent federal case law indicates that the courts will interpret the standing requirements liberally. In Montgomery Environmental Coalition v. Fri, 366 F. Supp. 261 (D.D.C. 1973) the court found that a general interest in the esthetic and environmental wellbeing of a river running through one's community would be sufficient to confer standing under the

act. The court then granted standing to a conservation group representing its members who lived in the community through which the polluted river flowed.

A citizen may bring suit against the EPA for failure to perform its duties under the Act, following notice to the agency and the sixty day waiting period (waived for the most serious types of violations). The federal district court in the area in which the discharge is occurring is granted jurisdiction over such suits. The court is given the power to issue a temporary restraining order, or a preliminary injunction, and may award costs of the litigation and attorneys' fees to the successful party. The EPA can be joined in any suit against a polluter and required to use its broad remedial powers to abate the pollution, correct the damage done to the general environment, and levy civil and criminal penalties against the violator.

2. Salt Marshes

Salt marshes are fairly flat beds of salt resistant vegetation that are alternately flooded and drained by salt or brackish water. In North Carolina, marshes are often found behind barrier islands, along the fringes of embayments and sounds, and along creeks, streams and rivers under tidal influence.

The marsh is a buffer or transition zone between the uplands and the marine environment. It has inputs and outputs of materials and energy to both bordering environments. Many of the important values of salt marshes are a consequence of this interaction.

The most notable direct value of the marsh is its function as a habitat for commercially important animal species. However, the vast majority of the services and functions the marsh provides for man are indirect and are not realized within the system itself. The marsh serves as a nursery ground for many commercially important species such as shrimp, mullet, menhaden, and striped bass and as a source of food and nutrients for other organisms. Man reaps the benefits of the marsh when he gathers shellfish from the estuary, or when he hunts or fishes. In addition, because of the efficient nutrient recycling that occurs there, it is believed that the marsh acts in a manner similar to a tertiary sewage treatment plant, and therefore reduces the effects of sewage disposal. Protection from flood damage and erosion control are also provided to the uplands by the marsh. Finally, the marsh offers esthetic pleasure and limited recreational activities such as bird watching.

a. Ecological Processes in the Salt Marsh

Many of the values mentioned above are reflected in the following list of processes which occur in the salt marsh:

(1) Variation in salinity due to intrusion of tides and differences in fresh water input which provides habitat for species requiring salinity change and species that can tolerate wide salinity changes

(2) Growth of plant matter (primary production) on which higher levels of the food chain are dependent

(3) Flooding and flushing of the marsh which provides for the exchange of pollutants, nutrients, and organic material between the marsh and the estuary.

(4) Sediment trap by marsh vegetation which allows accumulation of water borne materials

(5) Energy export and storage in the form of organic materials or detritus which is a major food source for marsh and estuarine animals

(6) Storage of nutrients, chemicals and toxic substances in the marsh which are flushed out at a rate more easily handled by the estuary

(7) Marsh vegetation's slowing of water velocity to provide physical protection for uplands area.

b. Process Disturbing Activities in the Salt Marsh

The following types of activities are destructive of the marsh and may to some extent eliminate the services it provides:

(1) Construction and development--The activities which precede development and which convert the marsh into developable land (such as dredging, filling, and bulkheading) eliminate the valuable functions which marshes perform.

(2) Bulkheading, channelizing, impounding (to create fresh water ponds) and ditching (to control mosquitoes)--These activities effect the flow and level of water in the marsh for purposes other than allowing development. Since marshes depend on

flooding, human activities that interfere with flooding regimes should be scrutinized carefully because they have an amplified effect on the marsh. These activities may impair the capacity of the marsh to carry out its natural functions, but the two latter activities have some benefit in terms of increased habitat for some animal species, and in some cases channelization may increase the productivity of the marsh.

(3) Dumping of spoils and pollutants--Both practices are destructive of the marsh with no countervailing value.

c. Policy Implications for the Salt Marsh

If development is allowed in marsh areas, two principles should be followed to minimize the losses caused by the destruction of the marsh environment. First, it may be preferable to develop in the less productive irregularly flooded marshes. Development in regularly flooded marshes should be prohibited or controlled more strictly than development in irregularly flooded marshes. It would appear that the differences in productivity give legal justification to regulating the types of marshes differently. The guidelines used by the Department of Administration in implementing the state dredge and fill permit system in general allow no alteration of highly productive regularly flooded marshes and some alteration of irregularly flooded marshes.

Second, a significant net loss of marsh acreage should not be permitted. Significant losses can be prevented by:

--requiring or encouraging developers to replant marsh vegetation in suitable areas to replace what has been destroyed.

--curtailing activities that impair the natural processes of the marsh but do not involve development. For example, ditching should be strictly controlled, and less destructive means of mosquito control should be promoted. The value in impounding a marsh should be weighed against the values (mentioned above) which will be lost. This course of action assumes that people cannot engage in all these activities to the extent they may desire without drastically reducing swamp acreage. The price of development may have to include the reversal of other practices which destroy the marshes.

--strictly controlling sedimentation and erosion and the dumping or discharging of substances which may adversely affect the marsh areas.

d. Management Tools and Techniques Applicable to Salt Marshes

Development and other activities which are destructive of marsh areas are currently regulated by state and federal laws which are implemented through state and federal permit procedures. It is important to note at the outset of the discussion of local tools that the state and federal dredge and fill laws will effectively prohibit most development. The dredge and fill acts are covered in more detail below.

It is also important to note that ownership of some marsh land is claimed by private citizens as well as the State. The tools and techniques discussed below will be less necessary if ownership is resolved in favor of the state, but should be considered by planners and local governments until such time as the claims are resolved.

(1) Local Tools and Techniques

(a) Presently authorized or available

Tools and techniques which may be used by local governments to regulate development in marsh areas are listed below:

i. Acquisition of less than fee interests (Appendix Two, Section I E)--Through this technique a local government buys the right to use a property owner's land or the right to prevent the owner from using the land for a specified purpose. An easement is a common example of a less than fee interest in property.

A local government could buy easements from the owners of marsh land to prevent development, but the cost of the easement would be almost as great as the cost of buying the land outright. Only in areas not yet subject to development pressures will it be possible to acquire easements at a modest cost.

ii. Fee simple acquisition (Appendix Two, Section I F)--Buying land outright is a certain way to protect marsh areas. The principal drawback to this preservation

strategy is the expense. Some sources of financial assistance for land assistance are noted in the appendix.

iii. The Nature Conservancy (Appendix Two, Section I J) --The purpose of the Nature Conservancy, a national conservation organization, is to preserve ecologically and environmentally significant land. TNC may be of help in preserving marshlands which the local government is unable to purchase. TNC acquires land through purchase using its General Fund, through donation by private individuals and organizations, through cooperative programs involving other public and private conservation groups, and through special programs of advance acquisition for local, state, and national parks, forests and wildlife refuges.

iv. Utilities extension (Appendix Two, Section II E)-- By developing policies on the extension of utilities such as water and sewerage, a community can control the location and type of development which will occur in specific areas. A municipality is not required to extend services beyond the city limits. Extension requests can be denied where there are reasonable economic and fiscal grounds for the denial. If development is dependent on the provision of services, a denial prevents development.

For example, if the development site is not suitable for septic tanks, the extension of sewerage facilities would be required before development could take place.

Extension policies may in some cases coincidentally promote a policy of protecting marshes and other sensitive areas from development. However, North Carolina case law does not specifically authorize environmental policies to form part of the basis for extension policies.

v. Access to utilities (Appendix Two, Section II G)--Policies on access to existing facilities may be used in the same fashion as extension policies which were discussed above.

vi. Performance standard zoning (Appendix Two, Section IV C 13)--A performance or impact zoning ordinance specifies the acceptable levels of side effects (such as noise or erosion) that development may produce. Unlike traditional zoning, it does not designate permissible uses. For example, performance zoning would allow industrial as well as residential development in the same zone provided specified levels of impacts were not exceeded.

This concept can be applied to marsh areas by devising a set of standards based on the natural processes of the marsh and the amount of interference with those processes

that can be tolerated. For example, standards may specify that water levels or rates of fresh and salt water flow cannot be reduced beyond a certain standard. Development which did not meet those standards could not take place. Adequate scientific data may or may not be available to serve as a basis for the standards, depending on which processes or which side effects are measured.

Performance standards based on the natural processes of the marsh could probably not discriminate between different types of development that take place in the marsh area because development will eliminate all of the natural processes in the area which is developed.

This tool would be more effective in regulating development outside the marsh which effects the processes in the marsh. For example, excessive erosion in upland areas could adversely effect the marsh. Acceptable levels of impact on the marsh could be designated and used as a standard for allowing development in the upland area.

This tool would also be effective in controlling activities other than development in marsh areas where the owner does not currently want to develop.

The power to zone by use of performance standards is not explicitly granted by state zoning enabling legislation and there are no North Carolina court cases dealing with

the technique. Performance standards would seem to be permissible when used not as a replacement for traditional zoning but in a less comprehensive fashion, e.g. for regulating areas of particular environmental concern.

Performance standards demand a case by case consideration of development proposals which would require a great deal of staff time. This may restrict its usefulness in jurisdictions which have not yet hired adequate enforcement staffs.

vii. Planned unit development (PUD) and cluster or average density zoning (Appendix Two, Section IV D 1)--Planned Unit Development (PUD) ordinances combine some of the characteristics of zoning ordinances and subdivision regulation. This type of ordinance generally applies to large developments which are planned as a unit with greater flexibility in design. The flexible regulations often permit the clustering of residential units to provide open space areas in the development. To the extent that clustering is used, this technique can be used to protect marshes in the manner outlined below in the discussion of cluster zoning.

PUD ordinances are not specifically authorized by enabling legislation in North Carolina. However, many local jurisdictions have such ordinances. Their validity has not been tested in court.

Cluster zoning allows a local government to set an average density standard for areas zoned for residential use. A developer is allowed to place housing units anywhere on the site so long as the overall density standard is not exceeded.

Thus, if a proposed development site includes some marsh land, the developer has the option of clustering the housing units in the upland area and avoiding development in the marsh. This technique will be most useful in protecting marshes from development when the marsh comprises a small portion of the proposed development. Its utility is very limited when the entire development is situated in the marsh, although conceivably a developer could find it attractive to build on some instead of all of the proposed development site.

Authority to use cluster zoning is not explicitly granted to local governments in state zoning enabling legislation. This technique may be upheld under the general grant of zoning power, but it would be desirable to amend the state enabling act to explicitly authorize the use of this tool.

viii. Traditional subdivision regulation (Appendix Two, Section IV D 2)--Subdivision regulations control the process of converting raw land into residential building

sites. Modifying standard subdivision regulations to protect environmental values seems to be feasible. The legal limits of this type of modification are not clear.

This technique does not seem to be useful in trying to prevent development in marsh areas. However, in a manner similar to the dedication of land in subdivisions, an ordinance might be developed to require replanting of marsh vegetation in suitable areas. This technique would be useful in protecting marshes from the adverse effects of nearby development. Subdivision regulations could be developed which specified permissible levels of runoff, restricted practices that obstruct the flow of water in and out of marshes, prohibit dumping of spoils and other substances or used performance bonds to ensure compliance.

(b) Other Tools and Techniques

i. Transfer of Development Rights (Appendix Two, Section I D)--Transfer of development rights could be used to protect environmentally sensitive areas such as marshes in the following way: development would be prohibited in marsh areas. The owners of marsh land could sell their development rights to developers in the rest of the community who would need to buy the rights to develop their own land. Marsh owners would be compensated by other

land owners for the loss of the right to build in the marsh.

Transfer of development rights is not specifically authorized by the general zoning enabling legislation, and specific authorization is probably required. The technique requires extensive research and staff preparation prior to implementation.

ii. Compensable regulations (Appendix Two, Section I G) --Compensable regulations are development regulations such as zoning which are implemented along with a system of compensation for decreases in property values caused by the regulation.

Compensable regulations are not specifically authorized by the state zoning enabling legislation. If compensable regulations are utilized at some point, the cost of the compensation may be prohibitive when applied to marsh areas. If the regulation prohibited development in marsh areas, the local government would have to pay the land owner approximately the price of the fee simple title. There would be no advantage to regulation as opposed to fee simple acquisition except that the land would remain on the tax rolls.

This tool is more effective when more limited regulation is desired and the local government is not trying to totally prohibit development. Other activities harmful

to the salt marsh such as dumping, ditching and impounding should be regulated, but there is no particular need to attach regulations to a compensatory scheme unless property values are significantly reduced by the regulation.

iii. Preferential assessment (Appendix Two, Section III E)--Preferential assessment is a system of taxation in which the tax assessor values a parcel of land solely on the basis of its current income producing capacity. To some extent this technique by reducing taxes would make it more likely that land owners would resist development pressures. It also reduces the tax burden on land that cannot be developed due to regulation.

This technique has not always been effective. At present in North Carolina, salt marshes are not among the categories eligible for preferential assessment.

iv. Bonus and incentive zoning (Appendix Two, Section IV C 2)--This type of zoning ordinance gives developers an incentive, usually in the form of increased financial return, to develop in a manner that will benefit the community. Usually the builder is allowed an exception to the zoning or regulatory scheme in exchange for providing some amenity that the local government desires.

In the context of environmental protection in the salt marsh, an ordinance could be devised which would, for example, allow increased density in exchange for the developer's promise to leave some of the marsh in its natural state. It would also be possible to give incentives to developers to install sewerage systems where such systems are desirable but not required.

Bonus and incentive zoning are not explicitly permitted by state zoning and enabling legislation. It seems possible that bonus or incentive zoning would be found illegal in North Carolina. (See discussion of legal problems in Appendix.)

(2) State and Federal Tools and Techniques

(a) Regulation of development in areas of environmental concern (Appendix Two, Section VI)--Salt marshes are included in the definition of "coastal wetlands" used in the guidelines to the Coastal Area Management Act and therefore may be designated as AEC's. Salt marshes are very likely to be finally designated as areas of environmental concern. They are the best defined environments listed in the guidelines, and will thus be the easiest to designate. Regulation of salt marshes through their designation as AEC's will probably be more effective than regulation of the other types of AEC's because the guidelines are to be used in conjunction with the dredge

and fill act which is a strong, effective regulation in and of itself. The appropriate uses of marshland as stated in the guidelines borrow heavily from state dredge and fill guidelines.

(b) Control of coastal wetland activities (Appendix Two, Section V B 13)--N.C.G.S. 113-230 authorizes the Secretary of Natural and Economic Resources to make orders controlling activities in designated coastal marshlands and designated contiguous areas for the purpose of promoting public safety, health and welfare, protecting property, wildlife and marine fisheries. The regulation of contiguous areas offers substantial potential for protecting coastal marshlands from damage due to septic tanks, sedimentation-producing projects, and other damaging activities adjacent to but not actually in the marshlands. Since its enactment, this statute has not been used by the Secretary, but it is a potential valuable tool for protecting marshlands.

(c) Dredge and fill permits (Appendix Two, Section V B 14)--N.C.G.S. 113-229, the dredge and fill act, authorizes DNER to implement the state permit procedure. The responsibility for carrying out the provisions has been delegated to the Division of Marine Fisheries. According to the act, an application may be denied upon finding: (1) that there will be significant adverse effect of the proposed dredging and filling on the use of the water by the public; or (2) that

there will be significant adverse effect on the value and enjoyment of the property of any riparian owners; or (3) that there will be significant adverse effect on public health, safety, and welfare; or (4) that there will be significant adverse effect on the conservation of public and private water supplies; or (5) that there will be significant adverse effect on wildlife or fresh water, estuarine or marine fisheries.

A federal dredge and fill permit (Appendix Two, Section V C 6) must be obtained from the Department of Army, Corps of Engineers.

DNER has printed a partial list of guidelines presently used by state and federal agencies in making permit decisions. The guidelines are reprinted in the appendix to show the extent of current regulations so that local governments can shape their own tools and policies to complement state and federal efforts. The dredge and fill laws do not prevent a local government from enacting further restrictions on activity in marsh areas through zoning or some other form of regulation.

Some of the most important guidelines are mentioned here. Alterations are allowed in irregularly-flooded marshlands depending on the extent of and the impact of the alteration. Alteration of highly productive regularly flooded marshland is not allowed. Applications for the construction of lagoons

or impoundments generally will not be approved if the area involved lies below the mean high water mark or involves significant wetlands.

(d) Regulations pursuant to erosion and sedimentation control plans (Appendix Two, Section V B 17)--Local governments are authorized to develop erosion control ordinances. The Sedimentation Pollution Control Act of 1973 included mandatory standards which are to be included in local ordinances. Where local governments fail to effectively implement such ordinances, the Sedimentation Control Commission under the DNER has the authority to develop and enforce ordinances for the locality. This type of ordinance can prevent the sedimentation of marsh areas by controlling construction and other activities in areas in proximity to the marsh area.

(e) The following state regulatory programs although less directly important than the preceding tools, may also play a role in protecting marshlands. Local governments should be aware of their existence and should plan to aid in notifying the appropriate agencies of any violations. Description of the programs are found in Appendix Two:

--Mosquito control districts (Appendix Two, Section V B 2)

--Prohibited discharges to water (Appendix Two, Section V B 3)

--Licensing of and regulation of pesticide application (Appendix Two, Section V B 10)

--Regulation of oil refineries (Appendix Two, Section V B 12)

--Oil pollution control (Appendix Two, Section V B 18)

--Regulation of mining operations (Appendix Two, Section V B 19)

--Regulation of oil and gas wells (Appendix Two, Section V B 20)

3. Mud and Sand Flats

Located between high and low tide levels throughout North Carolina's coastal zone are sandy and mud bottom areas commonly called "flats." Flats are exposed at low tide and include the areas extending out from the permanent shoreline as well as shoals and bars separated from the mainland by water.

Often these apparently barren mud flats contain an abundance of animal life, crustaceans, clams, and worms hidden away beneath the sediment surface. They can, therefore, serve as important feeding grounds.

North Carolina's mud and sand flats may be of slight commercial value in some counties where the commercial hard clam is dug by hand. Of greater importance is the indirect value of tidal flats as a feeding ground. Another indirect value of the flats is due to their role in trapping and cycling nutrients. This helps supply necessary amounts of nitrogen, phosphorous, and other nutrients to the overlying waters to be

utilized by microscopic plants vital to most estuarine food chains. Finally, there is an esthetic value to tidal flats. This comes from their interesting low tide bird populations which attract bird watchers to our coastal zone.

a. Ecological Processes

Several processes are vital to mud and salt flats:

(1) Many tidal flat organisms such as clams, snails, worms, and crustaceans, cannot survive without regular tidal flooding. The tides bring in organic matter called detritus which is an important food source for many mud and salt flat animals. In addition, many tidal flat fauna such as clams and worms can only feed and reproduce at high tide. At high tide the flats become a feeding ground for temporary animal members, including fish and crab.

(2) Flushing of the estuary is also an important process inherent in tidal flats. The outgoing tide carries waste and other accumulated materials out of the mud flat. During low tide, the flat becomes a feeding ground for birds, raccoons, rats and others. Also at lowtide the mud or sand buffers the organisms from drying, freezing and other stressful conditions and helps hide them from predators.

(3) Mud and sand flats also store and cycle nutrients. Much of the cycling is performed by bacteria which break down plant and animal matter to nutrients used by phytoplankton, an important link in the food chain.

b. Process Disturbing Activities

(1) The most harmful human activity is dredging and filling in or around mud and sand flats. Dredging in tidal flats removes habitat important for animals preyed upon by fish and birds and alters the sediment composition which diminishes the number and various types of animals. Dredging in nearby areas causes an increase in sediments in the water which may be deposited on tidal flats thereby smothering the tidal flat organisms and reducing oxygen levels.

(2) Another human activity harmful to tidal flats is discharge of pollutants, including sewage, gypsum spoils, insecticides, street runoff, and oil into the water. Sewerage increases the likelihood of large algal blooms which suffocate flat inhabitants, and gypsum spoils from the phosphate industry form a crust over the tidal flats, destroying clams, snails and other bottom dwelling organisms. Insecticides, street runoff and oil contaminate filter feeders like clams and snails.

c. Policy Implications

In deciding if development is allowed to destroy the tidal flats, the values of the flats must be weighed against the value of the development to the general public. Before direct development of any tidal flat is undertaken, studies should be made to assess the value of that particular flat. In terms of reducing the adverse effects of activities not taking place within the flats themselves, the following policies should be followed:

(1) Silt screens should be used during dredging and to reduce siltation problems

(2) Dumping, runoff and practices that introduce harmful substances into the tidal flats area must be strictly controlled.

d. Management Tools and Techniques Applicable to Mud and Sand Flats

It is important to be aware of the extensive state and federal regulation of activities occuring in tidal flats so that local regulations may be designed in a complementary manner. Dredging and filling of mud and sand flats is regulated by state and federal law. A summary of the guidelines used by the state and federal agencies which administer dredge and fill permit systems is included in Appendix Two. They indicate that development in tidal flats will be hard to justify. See also the discussion of federal regulations for permits for dredge and fill and for structures other than bridges in or over navigable waters in Appendix Two, Section V C 6. Because development in mud and sand flats is not anticipated, tools which protect the flats from development and activities in nearby areas are emphasized in the discussion of tools and techniques.

It is important to note that ownership of tidal flats which are below the mean high water mark is claimed by the State. Private citizens also claim ownership of most of the State's acreage of mud and sand flats. Because the outcome of these controversies is uncertain, local governments should regulate tidal flats as if they were in private ownership.

(1) One of the most useful tools which can be used by local governments to protect mud and sand flats is performance standard zoning (Appendix Two, Section IV C 13). This tool is a type of zoning ordinance which specifies acceptable levels of side effects of development without specifying which types of development are permitted. Any use (e.g. commercial, residential) would be allowed in the zone provided that certain levels of impact such as levels of erosion or noise were not exceeded. This tool would be most useful in the setting of tidal flats if it were designed to regulate development in areas near the flats which would have an effect on the processes occurring in the tidal flats. For example, an ordinance could be designed to prohibit development which would produce more than the permitted amount of sedimentation. This tool is discussed more fully in the Appendix Two, Section IV C 13, and in the section on salt marshes.

(2) The following state and federal tools are applicable to mud and sand flats:

(a) Regulation of development in areas of environmental concern (Appendix Two, Section VI)--Mud and sand flats which are contiguous to salt marshes will be included in the definition of "coastal wetlands" which may be designated as AEC's. In addition, tidal flats are areas subject to public rights which may be designated as AEC's.

The Coastal Area Management Act provides that major development in areas of environmental concern shall be required to receive permits from the Coastal Resources Commission, a regional administrative body made up of members appointed by the Governor. Permits for minor development may be administered by the city or county in which the development is proposed if that city or county has developed an approved enforcement program. If an enforcement program has not been approved the permit application is to be submitted to the Coastal Resources Commission. An application may be denied upon finding that the development would contravene certain existing orders concerning development of wetlands or estuarine waters; result in loss of long-range productivity; result in major or irreversible damage to historic, cultural, scientific, environmental, or scenic values; jeopardize public rights; unreasonably endanger life or property; or be inconsistent with state guidelines (especially in areas impacted by key facilities) or local land use plans.

The power to require permits will become effective when final designation of areas of environmental concern has been made, at which time the Secretary of the Department of Natural and Economic Resources shall designate the date for initiation of the permit procedure.

(b) Control of coastal wetlands activities (Appendix Two, Section V B 13)--N.C.G.S. 113-230 authorizes the Secretary of Natural and Economic Resources to make orders controlling activities in designated coastal marshlands and designated contiguous areas for the purpose of promoting public safety, health and welfare, protecting property, wildlife, and marine fisheries. Activities in coastal wetlands that can be effected by such orders include dredging, filling or other alterations such as removal of material. Since its enactment, this statute has not been used by the Secretary, but it is a potentially valuable tool for protecting tidal flats.

(c) Dredge and fill permits (Appendix Two, Section V B 14)--N.C.G.S. 113-229, the dredge and fill act, authorized DNER to implement the state permit procedure. The responsibility for carrying out the provisions has been delegated to the Division of Marine Fisheries. According to the act, an application may be denied upon finding: (1) that there will be significant adverse effect of the proposed dredging and filling on the use of the water by the public; or (2) that there will be significant adverse effect on the value and enjoyment of the property of any riparian owners; or (3) that there will be significant adverse effect on public health, safety, and welfare; or (4) that there will be significant adverse

effect on the conservation of public and private water supplies; or (5) that there will be significant adverse effect on wildlife or fresh water, estuarine or marine fisheries.

(d) Regulations pursuant to erosion and sedimentation control plans (Appendix Two, Section V B 17)--Local governments are authorized by the Sedimentation and Pollution Control Act of 1973 to adopt erosion control ordinances. These ordinances must be as strict as the standards set in the Act. If the locality does not adopt such an ordinance, then the state has the authority to adopt and enforce sedimentation control ordinances for the locality. By adopting this type of ordinance, a local government can prevent development and land disturbing activities in upland areas from interfering with the natural processes of the tidal flats.

(e) There are several other state and federal regulatory programs which control activities that may be harmful to tidal flats. Local governments should be familiar with these programs and be prepared to aid the state and federal agencies by notification of violations where necessary. These programs are discussed in Appendix Two:

i. Prohibited discharges to water (Appendix Two, Section V B 3)

ii. Licensing and regulation of pesticide application (Appendix Two, Section V B 10)

iii. Regulation of oil refineries (Appendix Two, Section V B 12)

iv. Oil pollution control (Appendix Two, Section V B 18)

v. Regulation of mining operations (Appendix Two, Section V B 19)

vi. Regulation of oil and gas wells (Appendix Two, Section V B 20)

vii. National Pollutant Discharge and Elimination System (Appendix Two, Section V C 3)

viii. Permits for dredge and fill and for structures other than bridges in or over navigable waterways (Appendix Two, Section V C 6)

4. Swamp Forests

Swamps are "land-water edge areas." They are wetlands characterized by a particular type of forest.

In North Carolina there are three types of swamps. Swamp forests or wooded swamps are found within sixty miles of the coast. Characteristics include an acid, peaty or mucky soil, short growing season, long flood period, few plants and shrubs, and a canopy of hardwoods, usually gum and cypress. The second type of swamps is river floodplain swamps or bottomlands found along streams from forty to one hundred miles from the coast. These swamps are more fertile than wooded swamps because of

alluvial sediments deposited by the rivers during floods. They have moist soils which support natural vegetation such as birch, sycamore, willow, and ironwood trees as well as agriculture. Pocosin swamps are the third type of swamp and are located within forty miles of the coast. They are typically waterlogged, with acid and highly colored peat soils, low in nutrients and fertility, generally characterized by pond pine trees.

Although swamps have been considered wastelands that need to be drained for agriculture and forestry uses, they perform many services and functions for humans seldom recognized. Among these services are water table maintenance, flood control, nutrient filtering and storage, and habitat for small fur-bearing animals, deer, black bear, bobcat, ducks and other birds.

a. Ecological Processes in Swamp Forests

Swamp forests are characterized by several processes:

(1) An important process is that of water table maintenance. By increasing the groundwater supplies lost during dry periods, swamps act to retard saltwater intrusion.

(2) Swamps also slow storm and flood waters by means of vegetation and soil and thus protect upland areas from storm damage and reduce upland erosion.

(3) In addition swamps act as nutrient storage areas by concentrating excess nutrients, chemicals and toxic substances in plant and soil. Since the productivity of swamps is limited by the acid and water logged soil, nutrients, chemicals and toxic substances are not recycled into a form that can be used in

photosynthesis. The result is a large pool of these materials in swamp areas which helps to buffer the concentration of these materials in the water against very high and very low amounts. In this way the inflow of nutrients, chemicals and other pollutants to the estuary is held constant so that the possibility of excessive growth of algae that cause oxygen depleted waters and thus fish kills, is reduced.

(4) By filtering the water by means of vegetation and soil, swamps act as sediment traps in which particulate matter settles out and is stabilized by vegetation.

(5) Swamps also provide a unique habitat for many small fur-bearing animals as well as ducks, birds, blackbear, bobcat, deer and fishes.

b. Process Disturbing Activities in Swamp Forests

Human activities that are most harmful in swamp forests are draining and clearing land and channelizing streams that run through the area. These activities are usually associated with forest and agricultural activity.

(1) Draining swamp environments can be hazardous because it encourages development in an area subject to occasional flooding and increases runoff. The increase in runoff is due to the drainage ditches which provide a horizontal path for water to flow directly to streams instead of vertically to the groundwater

supply. The result is a decrease in groundwater recharge and thus a reduction in the hydrolic head necessary to retard salt-water intrusion.

Ditching also reduces the soil's ability to absorb water, resulting in an increase in runoff to the downstream estuaries. In small tidal creeks the increase in runoff could cause serious changes in salinity as a result of an increase in fresh water input. This could affect shellfish, fish, and other organisms which may be sensitive to salinity changes.

Draining swamplands also adversely affects the peat soil characteristic of swamps. When dried, peat shrinks and causes the land to subside or compact. Dried peat has a tendency to further subside through a slow oxidation process. In addition, drained peat soils are fire prone. If peat is dried too much the result is a condition known as irreversible drying in which the soil permanently loses its ability to absorb and transport moisture.

In regard to vegetation, drainage alters the natural species consisting of hardwoods and pocosin types. Succession will eventually lead to the replacement of swamps with upland forests. (2) The effect of clearing swamp vegetation is a loss of the swamp's ability to trap and store nutrients, toxic substances and sediments, and to release these materials gradually to the estuaries. The result is an increase in nutrients, toxic substances

and sediments in the waters entering estuaries. Depending on the amount of increase in nutrients, eutrophication will occur, causing a decrease in oxygen available to shellfish, spawning organisms and others.

Clearing of swamp vegetation also results in a loss in the ability to retard flood water from upland areas. This in turn causes an increase in the frequency of downstream flooding.

(3) Channelization involves the widening and deepening of streams which results in changes in the stream bottom, aquatic vegetation and shore vegetation. Such drastic alterations of the natural environment destroy fish and wildlife habitats and diminish their populations.

Since channelization streamlines natural water channels, it, like drainage, increases the freshwater input to estuaries, thereby changing the salinity in shellfish and fish spawning areas. In addition, channelizing streams significantly decreases the soil's ability to retard floodwaters impacting downstream estuarine areas.

c. Policy Implications for Swamp Forests

Draining and clearing activities preclude any development, whether it be for agricultural, forestry, and urban use. As explained above, drainage and clearing inhibit the functioning of several important processes. Thus if development is allowed in swamp areas, drainage, clearing and channelization activities should be surrounded by a

buffer of natural swamp. Clearing and ditching near streams and groundwater recharge areas should be especially avoided. In this way the capacity of the swamp environment to filter out and store nutrients, toxic materials and sediments and to retard and absorb floodwaters will not be completely destroyed.

Disruption of the continuity of swamplands should also be avoided. Wildlife such as black bear and bobcat need large tracts in which to roam, and will not survive if swamps are divided into small tracts.

d. Management Tools and Techniques Applicable to Swamp Forests

Since swamps are characteristically wet most of the year, before any use whether agricultural, forestry or urban can be made of these areas, they must be drained by means of ditches. Ditching is regulated by both State and Federal regulations. Therefore since almost any development that is begun in swamps requires a State and/or Federal permit, local government development tools should be devised to complement State and Federal activity.

(1) Local Tools and Techniques

(a) Less than fee simple acquisition--This approach to acquisition of swampland involves the purchase of the development rights of the property as opposed to all the rights or the fee simple. Purchase of the development rights restricts the fee simple owner from full development of his land. Since the cost of developing swamps is so high, the cost of acquiring the development rights would probably be feasible for a local government interested in swampland for open space. (See Appendix Two, Section I E.)

(b) Fee simple acquisition--Since swamps are not very profitable unless drained and developed, the price of the fee simple may be only slightly higher than that of less than fee simple acquisition. Thus preservation of swampland as open space for public use might be achieved at a price affordable by local government (see Appendix Two, Section I F).

(c) The Nature Conservancy--This nationally based conservation organization has as its purpose the preservation of ecologically and environmentally significant land. Already it has negotiated the donation of the Great Dismal Swamp in Northeast North Carolina as a part of the American Land Trust. Thus if a swamp is of unique esthetic, ecological or other environmental value, the Nature Conservancy may wish to acquire it for itself or hold it in trust until the State of North Carolina is able to purchase it through the Land Conservancy Corporation (see Appendix Two, Section I H, and Appendix Two, Section I K).

(d) Utilities extension--A local government can influence the location of development by adopting policies concerning extension of utilities such as water and sewer. A local entity does not have to provide utility services to those areas outside its jurisdiction but justification for not extending services must be based on reasonable economic or fiscal grounds. In this way a proposed development in a

swampland outside a town's jurisdiction can be refused water and sewer service and since most swamp areas are not suitable for septic tanks, development can be limited by such a utilities extension policy. Septic tanks and water wells should be carefully controlled. Otherwise development using septic tanks and wells may proceed to a point at which the cumulative effect on the environment may be so adverse that the municipality may be compelled to alleviate the situation with the provision of water and sewer services not originally planned (see Appendix Two, Section I E).

(e) Access to existing facilities--Once utilities are available, the denial of access to these utilities is more difficult to justify than the initial policy not to extend services. This should be taken into consideration if services are to be provided to an area beyond an area, for example a swamp, where the extension policy is not to provide services and through which the services must be run to reach the area to be serviced. In this case there seems to be no justification for denying services to the swamp area through which the services will traverse. As in the case of utilities extension discussed above, in order to effectively prevent adverse environment impacts, the access to utilities policy should also discourage the self-provision of services such as septic tanks and water wells in areas where access is to

be denied. Otherwise the allowance of these private methods can lead to the extension of services in areas not originally designated because the cumulative effects of the private methods on the environment could necessitate the provision of water-sewer services (see Appendix Two, Section II G).

(f) Conventional zoning--Traditional zoning can be used in swamp areas to prohibit categories of uses incompatible with the ecological processes of swamps. Probably the best way to use zoning to protect swamps is to zone these areas for no use at all and requiring a special use permit for all development in swamps. In this way a project-by-project review can be made to forbid uses incompatible with swamp processes (See Appendix Two, Section IV C 1).

(g) Special exception--In the form of special use permits, this tool is used to review uses of swamps on a project-by-project basis. The use would be allowed in a swamp area only if it met the conditions or criteria specified in the ordinance. Conditions should be based on the effect of the development on the processes that are essential to swamps. For example the design of a structure in a swamp should not significantly interfere with the vertical drainage associated with groundwater recharge of aquifers in swamps and clearing over a particular magnitude should not be permitted. This technique can do much to lessen the impact of development on swamps and is expressly authorized in North Carolina (see Appendix Two, Section IV C 7).

(h) Performance zoning and performance controls for sensitive lands--This tool sets standards relating to the particular level of impact allowed for a development. If the standards specified in the ordinance are met then the development can take place in that zone. The standards for allowable impacts such as the level of sedimentation or vegetation removal should be based on scientific data if at all possible. This technique requires a level of technical expertise in setting standards and measuring impacts and so may be presently impractical for some local governments. It should not be overlooked in the future as more techniques for measuring impacts develop and as more scientific data becomes available. This technique is not explicitly allowed under North Carolina zoning enabling legislation and so should be used in conjunction with traditional zoning (see Appendix Two, Section IV C 14).

(i) Planned unit development and cluster or average density zoning--A PUD ordinance usually applies to a large development planned as a unit. The overall or average density of the planned unit development must meet the zoning requirements but individual portions of the unit need not. In this way the developer has greater flexibility in the design of a unit by permitting the clustering of structures and the provision of open space. With such an ordinance a locality can permit

a developer to cluster buildings on the part of a site that is capable of supporting such development and to leave a buffer of natural vegetation in the remaining portions. Since they are not authorized explicitly by North Carolina Statutes, caution should be exercised with planned unit development and cluster zoning ordinances to insure their use in conjunction with traditional zoning which is authorized by enabling legislation (see Appendix Two, Section IV D 1).

(j) Traditional Subdivision regulations--Subdivision regulations are commonly used to control the conversion of land into building lots and sites. Since these must be applied uniformly throughout a jurisdiction, it is difficult to design regulations applicable to a specific environment such as a swamp. However an ordinance can require the dedication of open space such as the swampland surrounding a proposed subdivision and occurring along nearby streams. This requirement could greatly lessen the impact of development on a swamp and its processes. Sufficient enabling legislation exists in North Carolina for subdivision regulation ordinances (see Appendix Two, Section IV D 2).

(k) Local health regulation--Local health boards can adopt rules and regulations concerning public health that are more stringent than those of the N. C. Commission of Health Services if a condition peculiar to that locality warrants

such action. In the case of wetlands, the water table is so high that it can easily be contaminated by septic tank effluents. This condition thus warrants the adoption of more stringent rules and regulations on septic tanks by local health boards (see Appendix Two, Section V A 1).

(l) Local environmental impact ordinances--This tool requires that the developer submit a statement on the impact which a development has on the environment. The purpose of the environmental impact statement is to give localities flexibility in guiding development in environmentally sensitive areas. Although local environmental impact statement ordinances require some technical expertise in the review process, a short form covering all the requirements specified in the North Carolina Environmental Policy Act of 1971 would not be too difficult to administer and would aid in the regulation of activities harmful to specific environments (see Appendix Two, Section V A 3).

(m) Transferable development rights--The purpose of transferable development rights is to compensate persons who own land in zones in which the property is restricted from full development. The first step in using transferable development rights is to designate a preservation district, in which development could not occur. The landowners in this district would then be given development rights in proportion to the

acreage owned, the developable value of the land or other criteria. These rights would then be marketed to persons in a designated transfer area who wish to develop their land at a higher density than allowed by the zoning ordinance.

The major drawback to transferable development rights is that this technique requires a new system of zoning and of transfering and recording development rights, requires technical expertise in creating and sustaining a market for the development rights and, in North Carolina, new enabling legislation. In spite of these technical problems, transferable development rights offers a method of compensation to owners of environmentally sensitive area for development restriction placed on their land and thus should not be overlooked in the future as the present difficulties are cleared up (see Appendix Two, Section I D).

(n) Compensable regulations--This is another tool designed to compensate the owner of environmentally sensitive land for the loss in property value due to development restrictions placed on the land. The assessment value of the property before the restrictions are imposed is guaranteed to the landowner at whatever time he chooses to sell the property. The utilization of this tool requires new enabling legislation (see Appendix Two, Section I G).

(2) State and Federal Tools and Techniques

(a) Control of coastal wetlands--The regulation of coastal wetlands specified in the N. C. Wetlands Act (N.C.G.S. 143-229 et seq.)calls for the Secretary of Natural and Economic Resources to issue orders regulating coastal wetlands (defined as marshlands) and surrounding areas for the purpose of protecting marshland from detrimental activities. Since swamps are usually found in the area surrounding marshes and are important in the protection of marshlands, a harmful activity such as contamination by septic tanks could seriously affect downstream marshlands. Thus this tool could be employed to regulate harmful activities in swamps that can result in the loss of protection of marshes and actual damage to marshlands (see Appendix Two, Section V B 13).

(b) Regulations pursuant to erosion and sedimentation control plans--Sedimentation pollution control ordinances can be adopted by local government in accordance with the Sedimentation Pollution Control Act of 1973. Such an ordinance can prevent an increase in sedimentation caused by extensive draining and clearing of swamp land for development. The ordinances must meet the mandatory standards of the Act and be approved by the N. C. Sedimentation Control Commission before a locality is granted the power to enforce sedimentation

controls. If localities do not adopt their own ordinance containing the minimum standards, the Commission can step in and enforce them. It would be advantageous for localities to adopt their own ordinances so they can design them to fit the needs of the community's environment and so that the localities can enforce them.

(c) National pollution disposal and elimination system--Through this permit system soon to be operated by the State Environmental Management Commission, the Environmental Protection Agency regulates the water quality of point source discharges and of receiving streams. Thus if a swamp is ditched or its streams are channelized for better drainage, the discharge from the ditches and the receiving streams must meet the water quality standards set for that stream. Thus this tool is valuable in regulating the ditching and channelization often used to drain most swamps for development (see Appendix Two, Section V C 3).

(d) Permit for dredge and fill--The state and federal permits regulating dredge and fill activities do not apply to freshwater wetlands, but the required permit for discharge of dredged materials does cover swamps and other freshwater wetlands. Since the dredging of ditches necessary to drain and thus develop swamps involves the discharge of the dredged material, dredging in swamps is indirectly regulated by a

permit from the Army Corps of Engineers. By supplying local input to the permit review process, a locality can in a sense influence development detrimental to the ecological processes of the swamps. In order to supply this input, local governments should make sure they are on the mailing list for notification of dredge and fill applications. This can be accomplished through the A-95 Review Process (Appendix Two, Section V B 22) conducted by the State Clearinghouse in Raleigh. (See Appendix Two, Section V C 6.)

(e) Regulation for development in areas of environmental concern--Although swamps do not make up a separate category of areas of environmental concern in the Coastal Area Management Act of 1974 or the Coastal Resources Commission Guidelines, parts of swamps can be designated AEC's under other categories such as aquifer, unique natural areas and areas containing remnant or endangered species (black bear, bobcat, osprey). If swamps are designated as AEC's, both minor and major developments will require a permit from the local government and the CRC respectively. (See Appendix Two, Section VI)

In conclusion, no one tool or technique is comprehensive enough to properly manage swamp forests. Many of the tools overlap. To adequately manage swamps, a set of tools and techniques suited to the particular needs of a locality

should be chosen from this list. Special attention should be paid to coordinating local regulatory tools with existing State and Federal regulations concerning drainage ditches in swampland.

GLOSSARY

Anadromous organism - one that normally lives in the ocean, but that migrates into fresh water to reproduce. Examples would be shad and striped bass. The opposite of catadromous.

Anaerobic - without air.

Anoxic - without oxygen.

Amino acids - the basic compounds that make up proteins.

Ammophila breviligulata - American beach grass. Salt-resistant grass used to stabilize sand movement. It is generally found further north than North Carolina.

Barrier island - an island roughly parallel to land lying between the land and the open sea with shallow water between the two.

Barrier island migration - movement of barrier islands with respect to the mainland.

Beach drift - floating material that is deposited on a beach (such as driftwood).

Beach nourishment - the process of bringing in sand (and other material) by man to replace that carried away by littoral drift (for example, the deposition of dredge spoil).

Beach profile - the beach viewed from the vertical plane. The intersection of the ground surface with a vertical plane; may extend from the top of the dune line to the seaward limit of sand movement.

Beach progradation - the building forward or outward toward the sea of a beach by nearshore deposition of river-borne sediments or by continuous accumulation of beach material thrown up by waves or moved by longshore transport.

Bedload - coarse material moving on or near the bottom.

Benthic organism - one that lives on the bottom, in or on the sediments.

Berm - a nearby horizontal part of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.

Blowout - a general term for a saucer-, cup-, or trough-shaped hollow, depression, basin, or valley formed by wind erosion on a pre-existing dune or other sand deposit, esp. in an area of shifting sand or loose soil, or where protective vegetation is disturbed or destroyed.

Bulkhead - a structure separating the land and water, primarily designed to resist earth pressures.

Catadromous organism - one that reproduces at sea and then migrates into fresh water to live as an adult. An example would be the American eel.

Copepods - small crustaceans which are the dominant group in the zooplankton; important as a food source for many organisms.

Cuspate foreland - a large, low mound or ridge of beach material occurring as a cape or as a broadly triangular point with the apex pointing seaward along an open coast. In some places, cuspate forelands can measure many kilometers from apex to apex and extend seaward for several kilometers.

Desication - drying up, dehydration.

Detrital organic material - finely divided material derived from and composed of decomposing matter of biological origin.

Detritus - finely divided settlable material, suspended in the water or on land; organic detritus - from the decomposition of the remains of organisms; inorganic detritus - settlable mineral materials. Often the term detritus is used to mean primarily organic detritus.

Dredge - to deepen using a machine known as a dredge (often a series of buckets on a conveyor belt).

Ebb tide delta - a roughly triangle shaped deposit of material left by the falling (ebbing) tide.

Ecosystem - the biological community and its environment treated together as a functional system of complementary relationships and the transfer and circulation of energy and matter.

Endemic species - a species confined to a certain country or region and with a comparatively restricted distribution pattern.

Eolian transport - movement of materials through the air or by the wind.

Epiphyte - a plant growing upon or attached to another plant, or often, on some non-living support, deriving no sustenance from the supporting structure, e.g. Spanish moss on a live oak.

Ethanol - a type of alcohol.

Eutrophication - the natural process of aging in bodies of water. The progression characteristically goes from relatively unproductive, low nutrient waters to highly productive, high nutrient waters that gradually fill with vegetable matter. Eventually a swamp or

marsh is formed, and finally, dry land. Large inputs of nutrients (sewage, fertilizer, and other pollutants) accelerate this aging process, however, and produce a distorted, unbalanced, and unfavorable increase in productivity.

Faunal provinces (Carolinian and Virginian) - along the east coast of the U.S., it has been discovered that the distributions of marine organisms fall into 2 groups - those whose range is generally to the north (ranging from about Cape Cod to about Cape Hatteras) and those whose range is more southern (Cape Hatteras to the tip of Florida). These so called "faunal provinces" are thought to be based primarily on mean water temperature over the year; the northern group being adapted to colder temperatures than the southern. Thus, variation in the flow of cold or warm water will often cause differences in the animals found in areas close to the "faunal break" (Cape Hatteras) and the exact location of a faunal province is therefore difficult to pinpoint. The northern faunal province has been called the Virginian province and the southern has been called the Carolinian.

Fill - either to put material in a hollow or low spot to create a level surface, or the material so used.

Flood-tide delta - a roughly triangularly shaped deposit of material left at the point of highest use of the tide.

Food web - the complex and interacting patterns of dependence for food, energy, etc. between organisms. In general, green plants form a base upon which other organisms build, ending with the largest carnivores.

Groin - a shore protection structure usually built perpendicular to the shoreline to trap littoral drift or slow erosion. It is narrow in width, and its length may vary from less than 100 to several hundred feet. They may or may not have openings permitting the passage of some littoral drift.

Habitat - the sum total of environmental conditions of a specific place that is occupied by an organism, population, or community.

Herbaceous - plants with characteristics of an herb (one or more stems that die back to the ground each year).

Herbivore - an animal that feeds primarily on plants.

Homeostasis - the maintenance of constancy or a high degree of uniformity in functions of an organism or interactions of individuals in a population or community under changing conditions, because of the capabilities of organisms to make adjustments

Hydrolic climate - a regime of water flow or motion.

Hydrolic head - 1) the pressure of a fluid on a given area, at a given point, caused by the height of the fluid surface above the point; 2) water-level elevation in a well, or elevation to which the water will rise to stop flow of water.

In situ - in place.

Interstitial - relating to or situated in spaces between closely spaced things. In most marine work, interstitial usually refers to things between sand grains or other sediment particles.

Intertidal - that part of the marine environment lying between the high water and low water levels of the tides. Literally, "between tides."

Jetty - on open seacosts, a structure extending into a body of water and designed to prevent shoaling of a channel by littoral materials, and to direct and confine the stream or tidal flow. Jetties are also built at the mouth of a river or tidal inlet to help deepen and stabilize a channel.

Lagoon-estuary - 1) lagoon - a shallow stretch of seawater, such as a sound, channel, bay or salt-water lake, near or communicating with the sea and partly or completely separated from it by a low, narrow, elongate strip of land (a reef, barrier island, sandbank or spit). It often extends parallel to the coast and may be stagnant. 2) estuary - a semi-enclosed body of water where freshwater mixes with and measurably dilutes seawater and where tidal effects are evident. In this report, the term "lagoon-estuary" refers to the lower energy ecosystems lying behind a barrier island.

Littoral drift - the material moved in the shore zone under the influence of waves and currents.

Longshore current - current in the surf zone moving essentially parallel to shore, usually generated by waves breaking at an angle to the shoreline.

Macrobenthic - organisms living on the sea bottom that are larger than 1 mm^2.

Microbial - having to do with microbes or microorganisms (bacteria, protozoa, etc.).

Nekton - organisms living in the water column, but able to move against currents; not dependent upon circulation patterns for movement.

Nitrification - the oxidation of ammonia and ammonium compounds to nitrates and then to nitrates by certain bacteria.

$$NH_4^+ + 1\ 1/2\ O_2 \rightarrow NO_2^- + H_2O + 2H^+$$

Northeasters - large storms whose winds blow from the northeast which occur primarily during the winter.

Overwash - that part of an advancing wave that carries over the crest of a berm or of a structure.

Oxbow - a more or less semi-circular meander of a stream or river. These meanders often form semi-circular lakes or ponds by separating from the main water flow.

Remineralization - the decomposition of organic substances to simpler mineral (inorganic) forms, e.g. proteins to nitrates, phosphates, etc.

Revetment - a facing of stone, concrete, etc. built to protect a scarp, embankment, or shore structure against erosion by wave action or currents.

Rhizome - an underground stem that produces shoots and roots periodically along its length (at the nodes).

Rip currents - a strong surface current of short duration flowing seaward from the shore. It usually appears as a visible band of agitated water and is the return movement of water piled up on the shore by incoming waves and wind. With the seaward movement concentrated in a limited area, its velocity is increased. A rip current is often miscalled a rip tide.

Riprap - a layer, facing, or protective mound of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embayment; also the stone so used.

Runoff - that part of precipitation appearing in surface streams. Literally, precipitation that is not absorbed by the ground and that runs off the land into streams.

Saltation - a method of sand movement in a fluid in which individual particles leave the bottom by bounding nearly vertically and because the motion of the fluid is not strong or turbulent enough to retain them in suspension, return to the bottom at some distance downstream. The travel path of the particles is a series of hops and bounds.

Salt spray - fine droplets of seawater blown up into the air and carried.

Seawall - a structure separating the land from the water (parallel to land) primarily designed to prevent erosion and other damage due to wave action.

Shelf circulation - water movement patterns on the continental shelf (nearshore waters out to about 200 m depth).

Shoals - detached elevations of the sea bottom made up of any material except rock or coral, and which may endanger surface navigation.

Sound - a relatively long, narrow waterway connecting 2 larger bodies of water or 2 parts of the same body, or an arm of the sea forming a channel between a mainland and an island; it is generally wider and more extensive than a strait.

Spartina patens, Spartina alterniflora - salt hay and salt marsh cordgrass respectively; grasses characteristic of a salt marsh environment.

Spit elongation - the length-wise growth of a small point of land or narrow shoal projecting into a body of water from the shore.

Spoil banks - sediment, earth, or rock excavated or dredged and placed into piles forming a mound or ridge or the raised edge of a stream, channel, cut or hollow.

Storm surge - that rise above normal water level on the open coast due only to the action of wind stress on the water surface.

Succession (ecological) - the natural replacement of one kind of community by another kind; the progressive changes in vegetation and animal life which may culminate in a "climax" or steady state community - one that persists for long periods of time.

Surf beat - irregular oscillations of the nearshore water level, with periods of about several minutes. Descriptively, surf beat is the variation in wave height that is often observed at the beach. Several larger waves break one after another, to be followed by several smaller waves and then the pattern repeats itself. This occurs because waves travel in groups or packets. Within each packet, wave energies build to a peak and then decrease - thus leading to groups of large and small waves.

Suspended load - the material moving in suspension in a fluid, being kept up by the upward components of the turbulent currents or by colloidal suspension.

Swash bar - a mound of material (fine sand, mica scales, bits of seaweed, etc.) left by a wave when it receded from its upward limit of movement on the beach.

Terrestrial - referring to land.

Tidal prism - the total amount of water that flows into a harbor or estuary and out again with movement of the tide, excluding any freshwater flow.

Trophic levels - levels (or "positions") of energy and matter transfer in a food chain or web. Traditional trophic levels include primary producers (green plants), decomposers, herbivores, and several

levels of carnivores. The concept of trophic levels is a general one, since in nature, most organisms operate at several.

Uniola pamiculata - sea oats. A grass resistant to salt spray damage, often used to stabilize sand movement on dunes.

Vascular plant - a plant possessing specialized tissues used to conduct water and food (respectively, xylem and phloem). These plants include all land plant groups except liverworts, hornworts, and mosses.

Washover fan - a fan-like deposit consisting of sand washed onto the shore during a storm.

Water column - pertaining to the entire water mass, from air/water interface to the water/sediment interface.

Wave refraction - 1) the process by which the direction of a wave moving in shallow water at an angle to shore is changed. The part of the wave advancing in shallower water moves more slowly than that part still in deeper water, causing the wave crest to bend toward being parallel with the underwater topography. 2) the bending of wave crests by currents.

Wave steepness - the ratio of a wave's height to its length.

Winnowing - the selective sorting or removal of fine particles by wind or water movement, leaving the coarser grains behind.